NPIC/TSSG/DED-1220-68
3 June 1968

MEMORANDUM FOR: Chairman, Operational Clearance Committee

ATTENTION : Chief, Security Branch, SSD/TSSG/NPIC

THROUGH : Chief, Technical Services & Support Group, NPIC

SUBJECT : Request for Security Clearances

1. It is requested that T, KH and SI clearances be granted to [redacted] Vice President for [redacted]

2. [redacted] technical representative through whom most of the NPIC requests are handled. The [redacted] has and is doing a very significant amount of business with NPIC with the nature of that business becoming increasingly more complex. In order for [redacted] to respond to NPIC's requests and to understand NPIC's problems, it will be necessary for them to have a representative who is familiar with the photographic materials, the computer hardware and software systems in use at NPIC.

3. At present, the [redacted] is fabricating the Twin Stage On-Line Comparator for NPIC. In order for them to properly evaluate the system design tradeoffs and to check out the final hardware which is on line to our computer, it will be necessary for one of their technical personnel to know the type and quality of the photographic materials and the photogrammetric programs utilized at NPIC. It is, therefore, requested that [redacted] be granted T, KH and SI clearances.

[redacted]
Acting Chief, Development Engineering Division,
TSSG

APPROVAL:

Chief, Technical Services & Support Group,
NPIC

Distribution:
Orig - Addressee
1 - NPIC/TSSG/SSD/SB
√3 - NPIC/TSSG/DED

02228

Approved For Release 2005/05/02 : CIA-RDP78B04770A001200010093-7

FINAL REPORT

TWIN-STAGE COMPARATOR

CONTROL NUMBER 02228

25X1

DECEMBER 3, 1969

1.0 INTRODUCTION

The Twin-Stage Comparator described in this report was designed and fabricated to demonstrate the technical soundness of the concept of using a single instrument to satisfy the requirements for photointerpretation and provide additional capability for obtaining precise measurements as part of routine photointerpretation. The resulting instrument is intended to bridge the gap between the high-precision mensuration equipment currently available to the photogrammetrist and the simpler instruments normally used by the photointerpreter. To achieve these goals the Twin-Stage Comparator was to provide the following features:

a. A high performance stereo viewing system having a wide range of available magnifications.

b. Twin X-Y coordinate stages with cut film holders to accommodate film chips up to 6 inches square.

c. Joystick controlled differential motor drive between the twin stage assemblies.

d. X and Y stage motions of 153mm with digitized readout for each of the four stage motions to a least count of one micro meter (.001 mm).

e. A data acquisition system to process signals from the X-Y digitizers and the control panel and convert them into a format acceptable for on-line computer use with a UNIVAC 494 central computer.

f. Be designed as compactly as possible and in accordance with correct human engineering principles for easy, comfortable, rapid operation. Mount the Comparator on a console equipped with castors and leveling screws so it may be easily moved and releveled. Finally the Twin-Stage Comparator system is to be designed for operation in a work area with 72°F (±5°) temperature and relative humidities of 55% (+15% to -5%).

The details of the Twin-Stage Comparator system resulting from these parameters are discussed in the following text. Specific problems encountered in the design, the problem solution, and an evaluation of the solution will be described in Section 8.0 of this report.

2.0 STEREO VIEWING SYSTEM

25X1 A [redacted] High Power Stereo Comparator Head was selected by the Customer as the viewing system for the Twin-Stage Comparator. The Stereo Comparator Head consists of two [redacted] Dyna Zoom Pods 25X1 having a continuously variable magnification from 1X to 2X. A magnification range from approximately 8X to 200X is provided with 6X and 10X [redacted] 25X1 Compensating Widefield Eyepieces and 1.3X, 3X, 6X, and 10X objective lenses. The objective lenses are mounted in a four-position centerable nose-25X1 piece. The [redacted] 3X, 6X, and 10X objectives are parfocal and require little refocusing when changing objectives. The 1.3X objective is a special wide 25X1 field lens manufactured by [redacted] Its primary use is to assist in locating points of interest on the film chip.

The Stereo Comparator Head was, however, modified by the [redacted] 25X1 25X1 [redacted] to extend the original distance between the optical center lines of the two objective lens turrets from approximately 12 inches to 18 inches and to provide independent fine focus adjustment for each leg of the optical system. The center line extension was accomplished by removing the objective lens turrets from the Stereo Comparator Head and adding dual optical relay systems. The turrets were then remounted at the termination of the mechanical structure. Both objective lens turrets were mounted on assemblies which could be translated to provide independent fine focus adjustments. This solution was selected as that least likely to deteriorate the performance characteristics of the Stereo Comparator Head as mutually evaluated at the time of its delivery by the Customer and the [redacted] 25X1 25X1 [redacted] The mechanical design for the modification of the Stereo Comparator Head was executed to physically locate the eyepoint for the viewing system at that position previously determined by evaluating a full scale mockup of the Twin-Stage Comparator from a human engineering aspect.

The zoom feature was considered essential in the stereo viewing system used on the Twin-Stage Comparator so that film chips having different scale factors could be matched optically by the photointerpreter to facilitate their inspection. The stereo viewer contains a fixed reticle in each optical leg. These reticles are located in an intermediate image plane rather than in the eyepieces to prevent displacement each time the interpupillary distance is adjusted. The configuration of the reticles employed and their dimensions are illustrated on the following page. This particular configuration was selected as that least likely to be disturbing or fatiguing to the operator based on the recommendation made to the Customer by a consultant in its employ.

The eyepiece angle was made adjustable to accommodate operators of different physical stature. Therefore, image rotation prisms were provided so image shifts resulting from an adjustment of the eyepiece angle could be corrected. Image shifts normally experienced when four-position objective lens nosepieces are employed with zoom optics were eliminated by specifying individual centering adjustments for each objective lens. This arrangement makes it possible to position each objective lens on the optical axis of the zoom optics so the image will remain centered in the viewing field throughout the 1X to 2X zoom range.

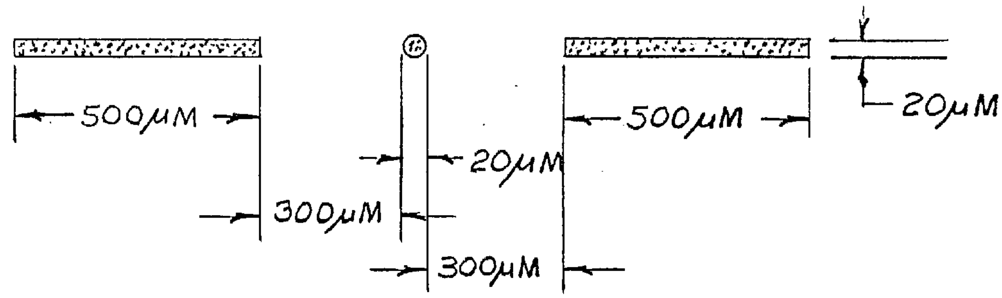
In addition to those design features already described, the speci-
25X1 fications to which [redacted] manufactured the High Power Stereo Comparator Head required that the internal optical elements be adjusted to satisfy the following requirements,

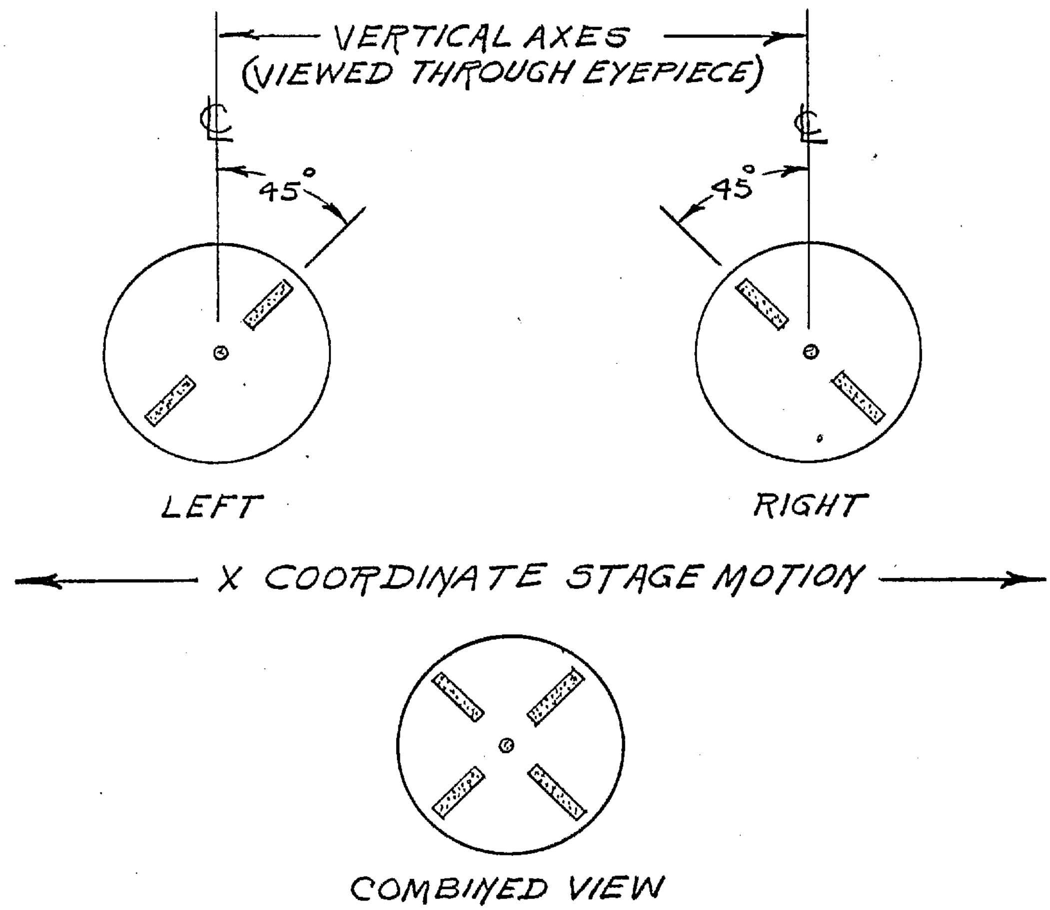
a. An image of a point in the object plane centered in the field of view would not move out of a 2.0 mm diameter circle centered in the eyepiece focal plane when the image rotation prism was turned through 180° (360° of image rotation).

b. The reticle dots would remain superimposed for all combinations of settings of the two objective lens sets.

c. Superimposition of the reticle dots would be maintained regardless of the interpupillary distance setting of the eyepieces.

INDIVIDUAL RETICLE CONFIGURATION





All these conditions were satisfied in the Stereo Viewing Head delivered with the Twin-Stage Comparator.

2.1 Viewing System Illumination

The illumination for each leg of the stereo viewing system is provided by a high intensity condenser type light source. The 100-watt tungsten iodide lamp utilized in the source operates at 3400°K. (The apparent color temperature is that of white light.) Heating affects on the instrument were minimized by locating the lamp at the rear of the instrument console and cooling it with a blower which discharges the heated air away from the instrument.

A variac for changing lamp voltage is used in conjunction with a series of neutral density filters to provide the capability for adjusting the intensity of illumination over a wide range without varying the apparent color temperature from that of white light. A variable diaphragm employed with the condenser optics provides the capability for matching the illumination to the various objective lenses used in the stereo viewing system. All control knobs for the two illumination systems are located on the forward edge of the instrument console within easy reach of the operator.

Spectral output of the tungsten iodide lamp is filtered to prevent the non-visible radiant light from reaching the film chip and causing dimentional changes that would adversely affect mensuration reliability. Filtering is accomplished by using a heat absorbing filter at the lamp in combination with the fiber optics bundle selected to transfer light from the condenser optics to the film stage. The filtering system is extremely effective as indicated by the 1°F temperature increase that resulted when a thermocouple was placed on a 1.5 neutral density filter located on the film stage. The 1°F increase, above ambient temperature, was measured after eight hours of continuous operation at maximum intensity. Mercury vapor lamps beneath the two film stages provide general illumination over the 6 in. square format to facilitate pre-selection of points to be measured.

3.0 X AND Y COORDINATE STAGE MOTIONS

Both sets of X and Y coordinate stages are capable of 153 mm of translation in the X and Y axes. These assemblies are mounted on a common Meehanite base. Each of the four stages is supported by selected high precision ball bearings and guided by guide shoes made from low coefficient of friction material spring loaded against the guiding way. The support and guide surface of each way is hand-lapped during instrument assembly to be flat and straight. Orthogonality of the X and Y coordinate axes are also adjusted during assembly to be within 5 sec. of arc. This is a proven technique that has been employed successfully over a period of years by

25X1 the [redacted] It is particularly advantageous for this application due to the weight of the stage assemblies and the high velocity (10 mm/sec.) at which they are required to move. Every effort was made to minimize friction loads resulting from translation of the stages so the precision setting and measuring accuracy capabilities of the Twin-Stage Comparator would not be jeopardized due to excessive heating and compression forces on individual precision lead screw assemblies. The measuring and readout system for the Twin-Stage Comparator will be described in Section 5.0 of this report.

3.1 Motor Drive

Variable stage drive speeds for slewing and point setting are accomplished by four velocity servo motors, one for each lead screw, with a single joystick control for all stage motions. Provision is made to enable an operator to select either the left, right, or both X and Y stage assemblies for translation. This feature is necessary to permit initial alignment of the stereo film chips. Maximum stage speeds of 10 mm/sec. are provided for rapid slewing and 5 micro meters/sec. (.005 mm) for setting on points selected for measurement. Also provided is the capability for selecting either one of the two X and Y assemblies as a master. A ratio control enables the remaining or follower set of stages to be set for differential speeds that range between 1 to 0.2 of master stage velocities (5:1 ratio). This feature makes it possible to translate stereo film chips having different scale factors with little or no realignment being required at successive points of interest.

Limit switches located at the extreme safe limits of travel of both sets of X and Y coordinate stage motions safeguard the stage and precision lead screw assemblies from accidental damage. Any of the four stages may be moved away from an activated safety switch by positioning the joystick to translate the stage in a reverse direction.

4.0 FILM STAGE

A film stage capable of accepting film chips as large as 6 in. x 6 in. square is mounted on the upper surface of each Y coordinate stage. The lower glass platen for the film stage is contained in a 360° rotary table which for purposes of simplicity and compactness was designed as an integral part of the Y coordinate stage. A gear drive is employed to provide both coarse and fine control of rotary table motions during initial alignment of film chips. A glass pressure platen, .062 in. thick, is used to hold the film chip flat. This thickness was selected as that sufficient to hold a 6 in. square film chip flat without unnecessary degradation of viewing system resolution which would have resulted if a thick piece of glass had been used. Contract specifications which required that image quality of film contained in the film stage and viewed by the modified stereo microscope be no less than 85% of those values obtained prior to addition of a pressure platen and modification of the stereo microscope were satisfied.

The film stage is capable of maintaining film in sharp focus over the entire 6 in. square format at magnifications in excess of 100X without a need for refocusing. At magnifications of approximately 200X the film will stay in sharp focus over any 1.0 in. square area of the 6 in. x 6 in. viewing area. The pressure platen for the film stage is hinged along one edge and equipped with a lifting mechanism to facilitate loading the film chip. Further, the upper pressure platen may be easily removed from its hinge assembly should it become desirable to accommodate film chips larger than 6 in. x 6 in. square. For such application the pressure platen is prevented from moving during measurement of the film by utilizing spring clamps supplied for use with the film stage.

5.0 FILM MEASUREMENT AND READOUT SYSTEM

Both sets of X and Y stage assemblies are translated with precision lead screws and have a measuring range of 153 mm. Optical shaft encoders geared through backlash compensation devices to the precision lead screws generate a pulse for each micro meter (.001 mm) of stage motion. A backlash compensation system was used so that measurements could be taken in either direction of motion of the respective stages without introducing a readout error. A data acquisition system mounted in an electrical cabinet adjacent to the Comparator provides a continuous visual display of the X and Y coordinate values for both stage assemblies.

A precision lead screw having a lead of 5 mm per revolution was used so a maximum stage velocity of 10 mm per second could be obtained without a need to cool the precision nut with a temperature controlled oil bath. This decision did, however, places more stringent requirements on the manufacture of the precision lead screws. This is due to the fact that multiple start lead screws are more difficult to produce than single start screws when accuracy requirements for each are equal. Use of a 5 mm lead screw also required a superior velocity servo amplifier in order to obtain the precise control necessary for slow-speed setting capabilities. Calibration data obtained for the precision lead screws during assembly showed the accuracy of the Twin-Stage Comparator stages to be as follows:

> "The actual stage position at any interval in its travel did not deviate from the position indicated by the digital readout system by more than 2.0 micro meters (.002 mm) or 2.0 micro meters plus .001% of the stage travel for measurements made over long distances."

The data acquisition system provided with the Twin-Stage Comparator will process and convert data from both sets of X and Y shaft encoders and from the control panel and convert them into a format acceptable for use by an on-line UNIVAC 494 central computer. Each time an operator commands that a position reading be made the digital values of the X and Y coordinate stage positions will be automatically read and these values along with other data inserted by the operator will be transmitted to the computer. The data system will then wait for an acknowledgment or error signal from the computer and, if necessary, the data will be automatically transmitted again. The digital coordinate values will be derived from the optical shaft encoders connected to each of the precision lead screws. Each of the encoders generate two voltages which will vary in a roughly sinusoidal manner as the encoder turns. Each voltage will complete 500 cycles per turn of the encoder and two voltages will be in phase quadrature. One of these voltages is fed to a pulse-forming circuit in the data acquisition system; this circuit will produce 1000 pulses for each turn of the encoder. The other encoder output voltage is used to determine the sense of encoder rotation. Gearing is used to rotate the shaft encoders at five times the speed of the lead screws so that one pulse is provided for each micro meter of stage motion. The pulses from each encoder are fed to a reversible counter. By adding or subtracting a count for each micro meter of stage motion, the counters will accumulate values which will provide a continuous indication of the position of the stages. Provision is made on the control panel of the data acquisition system for resetting the counters to zero and for setting them to preset values selected by the operator. A switch for each counter is provided for reversing the sense of counting. The coordinate values are displayed to the operator on four Nixie tube displays. Each display consists of six decimal digits plus signs. On command, the data acquisition system will generate a signal in the specified format and this signal will be fed through a cable to a remote computer. A signal generated by the computer acknowledging receipt of the message will be received by the system on another cable. The control panel, counters, signal processing circuits, power supplies, etc., are mounted in a single cabinet. Integrated circuits on plug-in are used for performing nearly all functions. In those cases where integrated circuits were not suitable for use because of their limited power handling ability, semiconductor circuits using discrete components have been used.

The type of integrated circuit logic used is TTL. Integrated circuits of this type, properly used, afford a high degree of immunity to noise, high speed, and excellent reliability. The availability of complex functions in a single TTL package reduces the number of interconnections and, thereby, further enhances reliability. Their small size allows placing much more logic on each card, reducing the number of cards required and further reducing the number of interconnections. The lower power requirements of integrated circuits as compared to discrete component circuits allows the use of smaller power supplies and effectively eliminates heat dissipation problems in most of the circuits.

6.0 OVERALL PHYSICAL CONSIDERATIONS

The physical size of the Twin-Stage Comparator and the instrument console designed to support it were kept at a minimum so they could be more easily moved. To facilitate moving the Comparator, the instrument console was equipped with castors and its width maintained at 35 in. so it would pass through 36 in. wide door openings. Leveling type vibration isolators adjacent to the castors provide a convenient means for leveling the Comparator after each move as well as protecting it from local external vibrations. The instrument console is a weldment fabricated from heavy guage steel to obtain maximum rigidity. Access panels are used to simplify the maintenance of components mounted within the wall of the console.

In order to evaluate a number of possible locations for operator controls on the console and the eyepoint for the stereo viewing system in accordance with correct human engineering principles, the [redacted] 25X1

25X1 [redacted] constructed a full scale mockup of the Twin-Stage Comparator. This mockup was utilized to determine the final location of all illumination and motor controls including the joystick. The position of the eyepoint and the viewing angle for the modified stereo viewing system were both changed from original specifications with the Customer's approval as a direct result of the knowledge gained from the mockup. The mockup also made clear the need for additional working space adjacent to the operator. This problem was alleviated by mounting a shelf on the electrical cabinet in a plane with the top surface of the instrument console.

The Twin-Stage Comparator is designed for operation from a single phase, alternating current power source of 120 volts, 60 cycles per second. Shielding has been provided wherever necessary to prevent circuits from being adversely affected by R.F.I. The instrument is grounded and precautionary measures taken to prevent electrical shock hazards. All electrical circuits are properly fused and/or interlocked to protect equipment and personnel. A warning light is provided to show when the power supply to to the system is switched on. Limit switches located at the extreme safe limits of travel of the X and Y coordinate stage motions prevent accidental damage to these assemblies.

To achieve maximum accuracy and dependability, the Twin-Stage Comparator is designed for use in a temperature and humidity controlled area. Further, the functional components chosen for use do not generate dust, lint, or other foreign matter which would prevent the instrument from being used in a "clean room" environment at some future date.

7.0 RELIABILITY AND SERVICE

The Twin-Stage Comparator is designed to withstand service usage under normal operating conditions for a period of 2000 hours (5 hours per day operation) without significant degradation of performance and with only minor maintenance due to normal expendable replacement parts.

The Comparator is designed to permit (1) ease of assembly and disassembly, (2) ready access to potential trouble sources, (3) maintenance with tools and equipment normally available to maintenance personnel, and (4) external test points. All necessary alarms, warning lights, and safety features are included to permit the most reliable and safe operation of the instrument possible. All high voltage areas have been labeled and/or interlocked for maintenance purposes. Chassis mounted in the electrical cabinet are supported by drawer slides to allow easy removal for maintenance. A metal cover fastened to the underside of each chassis prevents accidental contact with high voltage should the door at the rear of the electrical cabinet be opened while the system power is switched on. The fuses for all electrical circuits are located within the electrical cabinet and may be serviced by opening the rear door of the cabinet. A lock is provided on this door to prevent entry by other than authorized personnel.

8.0 PROBLEM AREAS

This section of the final report will describe the two major problems encountered in designing the Twin-Stage Comparator. These problems were, a. Measuring Accuracy and b. Stereo Viewing System. Each problem, its solution, and an evaluation of the solution based on data obtained with the completed instrument will be described in the ensuing paragraphs.

a. Measuring Accuracy

The problem was to monitor the position of the independent stages with micro meter accuracy while providing stage drive speeds of 10 mm per second. Additionally, these goals were to be achieved in a design aimed at simplicity, reliability, and ease of maintenance.

The experience and knowledge the [redacted] 25X1
has acquired designing and manufacturing accurate measuring Comparators over a period of years made it possible to avoid complex design for the stage drive and measuring motions. It was known that precision lead screws having a lead of one millimeter could not be employed to slew the stages at velocities of 10 mm per second without cooling the precision screw and nut assembly with a temperature controlled oil bath. Without an oil bath the heat generated during stage translation would be detrimental to measuring accuracy and could be sufficient to cause seizing between the precision lead screw and nut. Because the oil bath resulted in a more complex instrument, the decision was made to use a precision lead screw having a lead of 5 mm per revolution and support the stages on ball bearings to minimize stage friction. The 5 mm lead screw, though more difficult to manufacture, rotates five times slower than the 1 mm screw to produce identical stage velocities. The slower screw rotation coupled with free-moving stages was expected to minimize the heating and the mechanical loads on lead screw assemblies and result in micro meter measuring accuracy capabilities for all stage motions.

Evaluation of the data taken during calibration of the completed instrument showed that the accuracy requirements for each of the four precision lead screw assemblies had been satisfied. This data was obtained by measuring known distances with the Twin-Stage Comparator and comparing actual stage travel to the value obtained from the digital readout portion of the data acquisition system. Actual stage motion was determined by using the modified stereo viewing system to set on individual lines ruled on a glass scale. This scale had previously been calibrated by the National Bureau of Standards and the position of individual lines known to within one micro meter.

b. Viewing System

The problem was to modify a [redacted] Stereo Comparator 25X1
Head to increase the separation between the two optical legs and provide an independent focus adjustment for each. Further, these modifications had to be accomplished such that the image quality would be no less than 85% of those values obtained with the unmodified Stereo Comparator Head. In order to satisfy the performance characteristics described in the specification for the Stereo Comparator Head, it became necessary for [redacted] to adjust 25X1
various internal optical elements during assembly. In some instances these adjustments are difficult to achieve and critical to final performance. Because of these considerations, it was decided that the optical center line extension could best be accomplished by removing the objective lens turrets from the Stereo Comparator Head adding dual optical relay lens systems and remounting the turrets at the termination of the mechanical structures. This solution not only allowed critical optical adjustments to remain undisturbed, but enabled a sturdy lens board to be designed for mounting the relay optics and focus motion for each optical leg. Additionally, this solution afforded a means of locating the eyepoint at that position considered as optimum for an operator without need for a complete redesign of the Stereo Comparator Head assembly.

The independent focus motions use a parallel spring arrangement to provide a smooth motion which is free of both backlash and wear. The parallel spring focus motion was selected as ideal for this application because, once adjusted, focus is not adversely affected by external forces such as vibration. Evaluation of tests made with the modified Stereo Comparator Head justified the solution used, in that performance characteristics were greater than 85% of those values obtained prior to the modification and satisfied contract specifications. Focus, once adjusted, proved to be stable and remained unchanged when subjected to vibration.

9.0 SUMMARY

This contract has resulted in a new instrument that provides the photointerpreter with a capability for obtaining precise measurements as part of routine photointerpretation. The Twin-Stage Comparator described in this report was designed with emphasis being placed on system reliability, simplicity in design, measuring accuracy, ease of operation and maintenance, and the ability to be manufactured in quantity at a reasonable price.

Two important considerations intended to reduce the cost of additional Twin-Stage On-Line Comparators were the design of the precision lead screw assemblies and modification of the [redacted] Stereo Comparator 25X1
Head. The use of 5 mm lead screws provide the micro meter accuracy required without the need for temperature controlled oil cooling as explained in Section 8.0 of this report. This contract specified that a [redacted] 25X1
Stereo Comparator Head be purchased and modified to extend its normal 12 in. center line distance to 18 in. for use on the Twin-Stage Comparator. The method used to accomplish this 6 in. center line extension enabled the critical internal adjustments of the [redacted] Stereo Comparator Head 25X1
to remain undisturbed. This was deemed an important consideration in an instrument designed to permit quantity manufacture at a reasonable price.

CENTER ROUTING SLIP

FROM	DATE
TSSG/ESD	30 MAR. 70

TO		INITIALS	DATE
DIRECTOR			
DEP/DIRECTOR			
EXEC/DIRECTOR			
SPECIAL ASST			
ASST TO DIR			
ASST TO DEP/DIR			
CH/PPBS			
DEP CH/PPBS			
EO/PPBS			
CH/IEG			
DEP CH/IEG			
EO/IEG			
CH/PSG			
DEP CH/PSG			
EO/PSG			
CH/TSSG RED	X	P	31 MAR
DEP CH/TSSG			
EO/TSSG			
CH/SSD/TSSG			
PERSONNEL			
LOGISTICS			
TRAINING			
RECORDS MGT			
SECURITY			
FINANCE			
DIR/IAS/DDI			
CH/DIAXX-4			
CH/DIAAP-9			
CH/PFAD			

REMARKS

C/SDB
Bruce H.
Please comment
after thorough review.
R

IP FM 30 (11-68) - OBSOLETE PREVIOUS EDITIONS

MEMORANDUM FOR THE RECORD

SUBJECT: Interim Test and Evaluation Report Number 70-01 on the Twin Stage On-Line PI Comparator

GENERAL COMMENTS

1. Test and evaluation reports are disseminated throughout the community so as to enable anyone interested in an equipment to form an opinion as to the usefulness of that instrument. The report should be sufficient within itself to allow such an opinion by a reader unfamiliar with the instrument being described.

2. The T&E Report No. 70-01 on the Twin Stage On-Line PI Comparator is somewhat difficult to interpret and understand. The reporting is often fragmented with general statements in one place, details in another, and with no references leading the reader from one to the other. Not all the specifications in the development objectives for the Comparator were evaluated or referred to in the report. Subjective statements are made in the report with no substantiating remarks to explain to the reader the causes or reasoning behind some of the more subjective and general statements. In general, however, the testing and evaluation of the Comparator is thorough and capable. The above comments are directed more to the reporting than the technical competence of the evaluation.

SPECIFIC COMMENTS

SPECIFIC COMMENTS

1. Page 3, Section 1.2. "The objectives... were: (1) ascertain that all specifications have been met, ..." Not all the specifications of the development objectives were reported as having been tested. Appendix A is a list of specifications in the development objectives that were not reported.

2. Page 4, Section 2.2.1. "... stage motion is completely unpredictable." In what way is it unpredictable - speed, direction, smoothness? I feel the reader would like to know. Furhtermore, "...the stage moves at speeds varying from 5 micrometers ... per second." If such a slow speed is measurable, it does not sound completely unpredictable.

3. Page 5, Section 2.2.7. "... specified accuracy of 2 u m in 2 in..." The development objective specifies 2 u m in 1 inch.

4. Page 6, Section 2.3. "This exceeds the limits of 0.5 ma set by the Draft USA Standard..." This completely ignores the development objective requirement of no more than 30V and 2.5 ma.

5. Page 7, Section 3.2. "It is recommended, then, that the optical image rotator be deleted from the optics." Stage rotation sets up the base line of the imagery to allow mensuration. Once set up, you do not change this base line without destroying your measurement. To maintain stereo fusion, you must resort to optical rotation. The recommendation appears invalid.

6. Page 7, Section 3.3. "A fixed diaphragm... and degrade nothing." The following is a quote from the [redacted] 25X1

25X1 [redacted] Instruction Manual for the High Power Stereoviewer.

> "The substage iris diaphragm is provided to limit the angle of the cone of illumination to that value which is best suited to the subject under examination. Often, different diaphragm openings are required for different types of detail within the same imagery. Experience and attentive study are required to learn the most effective use of the diaphragm for increasing contrast and improving definition. The last use to which the substage iris diaphragm should be put is to control illumination intensity. This function is performed much better by the illuminator intensity controls and the use by the neutral density filters introduced between the light source and condenser."

7. Page 11, Section 5. There are two subsections - Acceptance Tests and Performance Tests. Acceptance tests are defined in Section 5.1 as "measurements of specified parameters." Performance tests are presumably tests other than those required by the development objectives. In Section 5.2, acceptance and performance tests are grouped together in such manner as to make it very difficult to determine what was in fact required by the development objectives and which tests were in addition to those required.

Approved For Release 2005/05/02 : CIA-RDP78B04770A001200010093-7

8. Page 13, Section 5.2.4. "Orthogonality was checked ...less than one micrometer." The development objective requires orthogonality within 5 seconds of arc. Reproting an orthogonality error of less than one micrometer is in itself meaningless. Assuming an error of one micrometer at a of 120 mm, the error is something like 1.7 seconds of arc.

9. Figure 6. This curve is tilted "Brightness vs. field of view with a 3X objective lens to be approximately 5.4 mm. Figure 6 appears to indicate a 10 mm field of view.

10. And other similar comments could be made as suggested by the penciled notes in the margins of the attached T&E report. In gneeral, results are usually reported without reference to the associated specification, and the reader is left to determine whether the results met specifications or not.

Approved For Release 2005/05/02 : CIA-RDP78B04770A001200010093-7

APPENDIX A

Specifications in the Comparator development objective not reported (numbers refer to sections in the development objectives)

3.0	6X6 free aperture. (Not reported)
3.0	6 inch movement in X and Y for stages. (Appendix, page 4, indicates this was checked but actual movement is unreported.)
4.1	18 inch separation between objectives. (Not reported)
4.1.4	20 micron reticle. (Appendix, page 4, indicates this was checked but actual size is unreported.)
4.1.6	(Illumination of unmodified High Power undetermined.)
4.1.7	20 ft-l at eyepiece with 2.0 density film. (Page 5 reports values with open gate.)
4.2.1	Film chips up to 6X6. (Not reported)
4.2.3	$\pm$ 3 inches independent translation of stages. (See 3.0 above)
4.3.1	Measuring range of $\pm$ 3 inches. (Appendix, page 4, indicates this was checked, Figs. 7-10 indicate 150 mm - 6 in = 152.4 mm - but measured value not reported.)
4.3.4	Orthagonal within 5 seconds of arc. (Orthogonality is reported on page 13 as an error of less than 1 micrometer. Assuming this error is at 120 mm from reference zero, the error is about 1.7 seconds of arc.)
4.5.2	20 ft-l. (See 4.1.7 above, and color temperature was not measured.)
4.5.3	(Color temperature variation not measured.)
4.5.5	Temperature not to exceed 100 F after 8 hours with 1.5 density. (Test was for 4.5 hours with 2.0 density film.)

4.7.2 Casters and leveling pads shall be provided. (Not reported).

4.7.5 Viewing stage approximately 32 inches from floor. (Not reported)

4.8.1 2000 hour reliability. (Not reported)

5.7 Noise. (Not reported)

INTERIM TEST AND EVALUATION REPORT

TWIN STAGE ON-LINE PI COMPARATOR

T&E REPORT NO. 70-01

INTERIM TEST AND EVALUATION REPORT

Twin Stage On-Line PI Comparator

March 1970

T&E Report No. 70-01

[redacted] 25X1

Test & Evaluation Branch
Engineering Support Division
Technical Services & Support Group
National Photographic Interpretation Center

CONTENTS

LIST OF ILLUSTRATIONS

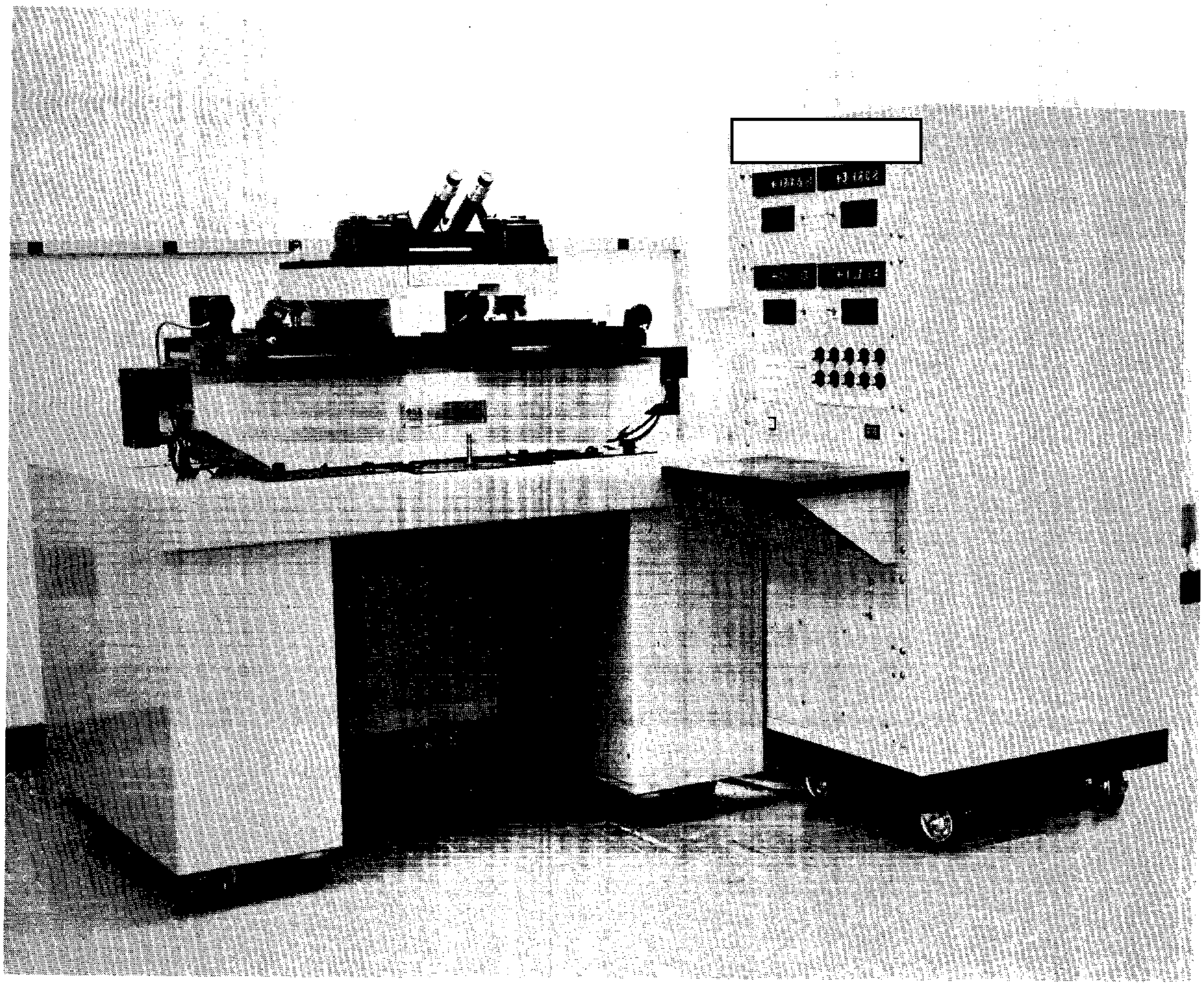


FIGURE 1. Twin Stage On-Line PI Comparator

ABSTRACT

The Twin Stage On-Line P.I. Comparator has undergone engineering tests. In general, the system is well designed. However, the stage motion and optics system have exhibited some characteristics which are to be modified or repaired by the manufacturer.

A safety inspection revealed the following: 1) The unit must not be operated without grounded cord, 2) A mechanical hazard exists when stages move to their closest proximity, and 3) The power switch lens reaches a temperature of 145°F.

25X1

([redacted] says 110°F max for surfaces exposed to bare skin contact)

Power switch "lens"? - located on console

1. INTRODUCTION

1.1 Equipment Objectives

The Twin Stage On-Line P.I. Comparator (TSC) was designed to provide the P.I. with the capability of obtaining precise measurements as a part of routine photointerpretation. Emphasis was placed on ease of operation, reliability, simplicity, and measuring accuracy. In addition to its capability for monoscopic mensuration, this comparator was designed to accomplish on-line stereo mensuration. This is also referred to as 4-axis mensuration.

The comparator was built by [redacted] The contract was monitored by TSSG/RED for IAS. 25X1

1.2 Test Objectives

The objectives of the test program which have been accomplished were: 1) ascertain that all specifications have been met, 2) uncover and request disposal of problems prior to operational use, and 3) evaluate performance in detail to assist in specifying follow-on procurement.

not all specs were reported as having been tested

2. SUMMARY OF TEST RESULTS

2.1 Acceptance Tests

Appendix 1 is the Acceptance Test Check List which was used. Inspection of this list shows that all required material was delivered, and that the specifications were met at that time.

2.2 Performance Tests

The tests summarized here were intended to explore the maximum capability of the machine. Since there are no clear specifications in most cases, the results are presented in narrative form.

2.2.1 Stage Motion System. The primary control is the "joystick". As shown on the Acceptance Test Check List, the stage moves at speeds varying from 5 micrometers to 10 millimeters per second. At joystick deflections of 5^o or less in any direction (from the vertical or "off" position) stage motion is completely unpredictable. in what way - unpredictable - speed, direction

At larger deflections, direction of stage motion changes with joystick deflection. The two stages do not move together in a manner that will permit an operator to maintain stereo fusion while measuring, regardless of deflection angle or direction.

2.2.2 Illumination System. The substage illumination system provides approximately 200 foot-lamberts (ft-l) of luminance to aid in film positioning.

The optics illumination system delivers a maximum 28,500 ft-l on the left side, and 22,500 ft-l on the right side. The difference is not noticeable. Table 1 is a listing of this data. 28500 - 22500

Calculations of density from light readings on the platen show that the filter densities specified in the instruction manual are not exact. In one case, calculated density is 0.57, while 0.50 is specified. However, the right and left side calculations show that they are matched, right to left, within 2%. (See Table 1) .50 densities specified

The diaphragm in the illumination system was designed to match the illuminated area on the platen to the field of view of each objective lens. However, the illuminated area, when the diaphragm is set at the 10X position, is not small enough to produce a noticeable gradient with the 3X objective lens in the optical train. It merely raises the light available at the eyepiece by 4.75%. (See Fig. 6)

(m) match with N.A.

ILLEGIB

The light passing through the optical train was measured with a scanning micrometer eyepiece containing a fiber optic[5] sensor. An additional test was necessary to measure light loss through the 10X eyepiece, since the comparator eyepiece could not be used in the previous test. Readings of 9.9 ft-l are available on the left and 7.1 ft-l are available on the right at 200X. This is through the total optical train without film of any kind on the platen.

$\frac{7.1}{22500} = 0.032\%$ $\quad \frac{}{28500} = 0.035\%$

A temperature rise of 1.8°F. (left side) and 2.6°F. (right side) was noted after $4\frac{1}{2}$ hours of operation at maximum illumination. The temperature was read on the platen under 2.0 density film.

illumination ?

No change in the output of the lamps was noted with varying line voltage from 110v to 120v.

2.2.6 Optics. The prime specification on the optics was that the modified [redacted] Stereoviewer should retain 85% of the image quality of the unmodified instrument. Resolution of the original optics was read at 960 lines/mm at 200X. Resolution of the right side degraded from 854.4 lines/mm, as reported on Acceptance Testing, to 760.8 lines/mm at the time of performance testing. It is now below specification (see Table 2).

25X1

The field of view was to be that of the unmodified [redacted] Stereoviewer. The specification for this field of view was supplied to [redacted] by the Center. The measurements made on the field of view show an average decrease to 87% of the unmodified field of view from that specification. However, the field of view of the unmodified instrument was not checked (see Table 3).

25X1
25X1

Therefore, the measured FOV for the particular instrument supplied [redacted] was never determined, and modified FOV cannot be compared to the unmodified

25X1

The focusing of the 1.3X and 3X objective lenses is inadequate. In both right and left optical paths, focus adjustment ends just as they came into focus, or before they are focused.

(P 4.1.5)

The development objective states that "the image will remain in focus throughout the zoom range." In 6 of the 16 right-left-eyepiece-objective lens combinations, it does not remain in sharp focus from 2X to 1X zoom.

2.2.7 Measurement Accuracy. Certified calibration data provided by the manufacturer shows that the specified accuracy of 2 μm in 2" has been met. This ... d.o. specifies 2 μm in 1"

2.3 Engineering Evaluation

The Twin Stage Comparator has been well designed. The construction is rigid so that the vibrations prevalent in the test area floor do not cause visible image vibrations, even at 200X.

imagery or vibration wedge

ILLEGIB

The electronics rack provides easy access to the chassis for servicing. Test points are not provided external to the chassis, but are accessible by the use of extender cards within the chassis.

A leakage current check shows that, with the TSC operating in an ungrounded condition, there is a potential of 56 volts and a leakage current of 8.5 ma from the TSC frame to ground. This exceeds the limits of 0.5 ma set by the "Draft USA Standard for Leakage Current for Appliances" sponsored by Underwriters Lab., Inc., published January 1969. The instrument is supplied with a 3-wire grounding cord, so that the hazard does not exist without unsafe practice by the operator.

The minimum separation of the two stages is 0.250 inch. If some part of the body were inadvertently in this area, it would be crushed. If some hard foreign object were there, the stage drive system would be severely damaged.

The backlighted main power switch reaches 145°F. This constitutes a hazard. The function indicator lights reach 111°F. This is above the permissable temperature level.

110°F is permissible

3. CONCLUSIONS & RECOMMENDATIONS

The overall design and workmanship of the TSC is very good. However, it is the first of its kind to be brought into the Center. There have been some problems noted in the equipment as built. There are also some changes which should be made prior to any follow-on contracts.

ILLEGIB

3.1 Stage Motion

The stage motion system is erratic at low stage speeds. It is impossible to maintain stereo while moving from one point to another on the imagery. Since the primary comparator function is low speed pointin some modification must be made to assure the accuracy and controllabilit of low speed, small movement operation. It is possible that the high slew speeds (10 mm/sec) could be traded off for increased controllabilit at low speeds.

3.2 Image vs Stage Rotation

Because the images must be moved after stereo fusion is realized, optical image rotation can be used only when each optics path is rotated exactly the same number of degrees.

ILLEGIB

For this reason, the stage rotation is the proper tool for rotation in setting up. A 90° turn of a stage requires 70 complete turns of the stage rotation control. Therefore, provision should be made to disengage the handwheel for gross rotation. This would allow rapid movement by hand when setting up. The handwheel could be engaged for fine movements to achieve good stereo fusion.

After stereo fusion is achieved, the image rotation on the optics could be used. However, this confuses the use of the joystick because the direction of apparent image motion will not follow the deflection of the joystick. It is recommended, then, that the optical image rotator be deleted from the optics. [illegible] sets up the base line of the imagery to allow mensuration. Once set up you do not change this without destroying your measurement. To maintain stereo fusion you must resort to optical rotation.

3.3 Diaphram

The changeable diaphragm included in the optics illumination train should perhaps be deleted. No perceptible illumination gradient is visible through the optics when the 1.3X objective lens (11 mm field of view) is used with the diaphragm setting intended for the 10X objective lens (1.5 mm field of view). A fixed diaphragm equal to that of the 10X setting will raise the light level at all optical power settings and degrade nothing.

See ¶ 11.2.2.4 of High Power Stereoviewer Instruction Manual

3.4 Mechanical Interference

When the stages are rotated so that the edges of the film hold-down frames are not parallel to the ways, the objective lenses can be run into the frame when the stages are transported. This situation could be corrected by lowering the frame 0.062 inches. There is adequate material on the frame for this modification.

3.5 Focus

The objective lens focus adjustment is not adequate for the 1.3X and 3X objective lenses. The adjustment travel ends just at, or before, these lenses came into focus. This must be corrected. The optics must be made to stay in focus from 2X to 1X Zoom.

3.6 Safety

A warning notice must be placed in the operator's manual and a warning tag must be placed on the power cord stating that the instrument should not be connected to an ungrounded outlet. The voltage and current leakage are potentially hazardous, and steps should be taken to eliminate this hazard.

The temperature of the main power switch lens must be lowered, if at all possible. If not, accidental contact with this lens must be prevented.

Some action must be taken to relieve the mechanical hazard existing in the table motion system (see 2.3). A shield or a proximity cut-off is a necessity.

4. DESCRIPTION OF EQUIPMENT

The TSC is comprised of 4 main systems: 1) stage motion and measurement, 2) illumination, 3) optics and 4) electronics.

4.1 Stage Motion System

The stage motion system is controlled by the following: 1) A joystick which can be deflected in any direction and at angles of up to 15^{o} from the vertical, 2) a rocker switch which determines whether the left, the right, or both stages move in response to the joystick, 3) a toggle switch which, along with the stage speed ratio potentiometer, controls differential stage speeds for viewing film of differing scales. These controls are located on the comparator.

The direction of deflection of the joystick determines which of the velocity servo motors operates -- left or right deflection provides voltage only to the X-axis servo motors, up or down (from the operator's position) provides voltage only to the Y-axis servo motors. Any direction of deflection in other than these causes a combination movement. The speed of movement is proportional to the amount of deflection from the vertical. Stage rotation is accomplished by means of a worm and spur gear arrangement. Each stage rotates individually and continuously.

Measurement is accomplished by coupling optical shaft encoders to the lead screws which drive the stages.

4.2 Illumination System

The optical illumination system contains a 100 watt tungsten halide lamp with a quartz envelope as the illumination source. This illumination is focused on the film platen by a condenser lens and a fiber optics bundle. In addition, there is a variable diaphragm system, and a set of neutral density filters in the illumination system.

The diaphragm has distinct settings for each of the four objective lenses. The theory is to present an illuminated area to the optics which is the approximate size of the objective's field of view.

The neutral density filters have nominal values of 0.5, 1.0, and 1.5. There is also an open position which provides no filter to the optics illumination.

The lamps are controlled by potentiometers which can vary their output from 0 to 100%.

The entire film platen can be backlighted for positioning the area of interest under the optics.

4.3 Optics

The optical system is a modified [redacted] Stereocomparator 25X1 Viewing System. It contains the following features: 1) 4 objective lenses (1.3X, 3X, 6X, 10X) in a rotating turret, 2) 2X to 1X Zoom settings in each optical path, 3) fixed reticles in each path, 4) tilting eyepieces which provide comfort for operators of varying heights, 5) IPD adjustment from 55mm to 72mm, 6) optical image rotator continuously variable from 0 to 360° in each path and, 7) interchangeable eyepieces, 6X and 10X.

4.4 Electronics Console

The electronics package contains all power supplies and the main switches, the measurement read-out, pre-set and reset controls for the readouts, and computer interface controls and electronics. The arrangement of the computer interface panel is identical to those already in use throughout the Center.

The TSC can be used with the NPIC stereo mensuration program and, by changing external cables, it can also use the NPIC monoscopic mensuration program.

5. TEST DETAILS

5.1 Acceptance Tests

The acceptance tests (see Appendix 1) consisted of 1) inspection to be certain that all deliverable items were included and 2) go-no go measurements of specified parameters.

The accuracy of the comparator was certified by the manufacturer. The procedure used by the manufacturer was repetitive measurements from 0 to 150 mm on a glass scale. The temperature of the scale and the comparator were closely monitored in order to supply temperature correction to 68°F. Figures 7 through 10 are the calibration certificates supplied with the machine.

ILLEGIB

5.2 Performance Tests

"Performance tests" are also [illegible] in "Acceptance Tests"

Envelope dimensions of the TSC are 52" high, 48" wide and 34" deep. The comparator itself weighs 735 lbs. The electronics cabinet is 55" high, 23" wide and 26" deep. It weighs 300 lbs, and has a 10 x 17 writing surface which can be shifted to allow the cabinet to be placed either on the right or the left of the comparator (see Fig. 5).

Total power requirements were measured at less than 600 watts (5 amps @ 117 volts).

5.2.1 In order to test the stage motion system, the joystick was positione at a precise direction and angle of deflection. An attempt was made to measure stage velocity versus angle of deflection. Results showed that no precise calibration (velocity vs angle) was possible since the data was not repeatable.

The capability of moving the two stages together was checked. With the "master" switch in both the left and right positions, and at a stage speed ratio of 1, the X & Y movements of the left and right stages were compared. Of the 8 primary directions checked, only 1 exhibited adequate control under those conditions. [illegible] compass directions, "ade

controllability of what

In attempting to check controllability at all combinations of control settings, ratio settings, and joystick deflections, a total of 840 readings were taken. Of these readings, 258, or 30.7% were within 5% of the expecte value. what was the expected value — without knowing the expected value these percentages are meaningless.

Stage rotation is accomplished by the use of a worm and gear system. It requires 280 turns of a 0.75 inch radius hand crank for a 360° rotation of each stage.

CONFIDENTIAL

Gamma Scientific, Inc. Model 2020-1 Photometer

5.2.2 The illumination system was tested using a Gamma Model 2020 Photometer with a fiber optics probe and various attachments. The luminance through the optics was measured with a fiber optics micrometer eyepiece. The instrument with attachments was calibrated with the Gamma 100 ft-1 source prior to the test. Acceptance test

One part of the optical train, the eyepiece, was deleted from these measurements. The transmission of the 10X eyepiece was checked using the Weston 759 foot-lambert meter. [illegible]
Where is this reported?

The maximum output of the luminance sources was measured at the stage. Ground glass with neutral density of 0.05 was placed on the film platen in order to provide a diffuse surface for luminance measurements. The fiber optics probe was then used, with the photomultiplier and neutral density filters in the photomultiplier, to read the luminance at the film plane. Readings were taken at all filter and diaphragm settings. ([illegible]
at all combinations of filter and diaphragm settings — See Table I)

Table 1 is a summary tabulation of the data taken for these tests. Figure 6 is a plot of brightness vs position in field of view for the 3X objective lens at 3X and 10X diaphragm settings. Acceptance test

With the optics illumination at maximum and the diaphragm set at 10X, film of 2.0 density was then placed under the auxiliary film clips, completely covering the glass platen. A thermistor was placed under the film at the illuminated area and the temperature was monitored for 4.5 hours. During that time the temperature rose from 79°F. to 80.8°F. on the left side, and from 78.2°F. to 80.8°F. on the right side.

ILLEGIB

The substage illumination was turned on. Readings were taken at 4 points on each platen through ground glass of neutral density of 0.05 since a diffuser is not part of the system. The readings varied from 1 ft-1 to 252 ft-1. This system is adequate for its intended use.

A variable transformer was connected to the power line of the TSC. The voltage was varied from 110 VAC to 120 VAC. There was no change in optics illumination output.

5.2.3 The resolution of the optical system was checked by 3 observers using a 240X reduction of the USAF 1951 configuration bar target. This target has been checked and found good to Group 2 Element 4 (1358 lines

@ 200X

The maximum resolution on the left side was 854.4 lines/mm. This group/element was read by all 3 observers. On the right side, the maxi was 760.8 lines/mm. This value was read by 2 observers, with one obser reading 604.8 lines/mm. This low reading is judged to be an error. Table 2 is a tabulation of this data.

The focusing system for the objective lenses physically moves the lenses either toward or away from the film plane. This is a modification of the original system. The 1.3 and 3X lenses cannot move far enough from film plane to move through the focus position. In order to sharply focus the 1.3X objective, it is necessary to use the reticle focus arrangement, which defocuses the reticle. The 3X lenses will come into focus, but it is not possible to move through the focus range to defocus above the film plane.

The optics will not always remain in focus from 2X to 1X zoom. This problem exists with the 1.3X objective lenses in position using the 10X eyepieces on either side. It is also evident on the right side with the 3X and 6X objectives and the 10X eyepiece in use. On the left side, the 3X objective and the 1.3X objective and the 6X eyepiece combination also defocus from 2X to 1X zoom.

It was stated in the development objective that the instrument must remain in sharp focus over a 2 in. square at 200X. The instrument met th requirement. As an additional test, a resolution target was placed under each corner of both stages, and focused at the front right corner of each The resolution was read at each corner. Figure 11 shows the readings obtained. Note that the right side top left was out of focus under these conditions. *Not called for in specs*

The field of view was measured by using the comparator itself. A line was transported from one extremity of the field of view to the other. The readings were taken directly from the output display on the electronics cabinet. Table 3 is a tabulation of this data.

There is an interference between the optics and the stage drive system. The 10X objective lens projects below the level of the glass hold-down frame. If the stage is rotated, and transported, this can cause damage to both the optics and the stage drive system. It was measured that the 10X lens, when in position and in focus on the film plane, is 0.040 inches below the level of the frame. This lens is closest to the film plane when focused. If this interference can be eliminated, no other interference will exist.

5.2.4 4-axis X & Y accuracy data was supplied by the manufacturer. These calibration certifications are included as Figures 7, 8, 9, and 10.

Orthogonality was checked by the use of a 120 mm calibrated scale. Diagonal measurements were taken so that, if orthogonality errors existed the readings would show the magnitude of theerror. Inspection of the data indicates that orthogonality errors are less than 1 least count of the measurement system, that is, less than one micrometer.

5.3 Engineering Evaluation

The safety of the TSC was closely inspected. There is some electrical leakage if the TSC is operated without a grounded power cable. The leakage is 8.5 millamps @ 56 volts AC. *0.5 ma is limit - See 19.6*

The moving stages can come within 0.25 inches of each other. There is enough power involved to injure a hand or finger which inadvertently got caught between them. To alleviate this, either a guard should be erected along the front of the TSC to prevent anything being placed between the stages, or a proximity switch bar should be mounted between the stages to stop all motion when contact is made between the stages.

The main power switch is backlighted by 28 VDC bulbs. This causes the lens to reach a temperature of $145^{\circ}F$ maximum. This is not in itself a safety hazard, since contact with this lens is momentary and infrequent. However, an inadvertent contact by unprotected skin, such as an elbow, could cause an involuntary jump leading to injury. It is suggested that either the temperature be reduced or the lens be shielded to all but perpendicular finger contact.

The construction of the table provides access to all components which may need service. This includes film illumination lamps, electronics and fuses. The measuring stages and optics mount are heavy castings securely joined which provide good rigidity. Shims have been provided to protect against damage to the ways when the TSC is moved from place to place. However, this movement should be kept to an absolute minimum.

During the time that the TSC was being tested, some opinions were formed as to problems which might be encountered during operational use. One of these is the problem of stage rotation vs optical image rotation.

In order to achieve stereo fusion, one of the stereo pair in use must be rotated to superimpose one or the other. They both must be rotated to provide the proper base line. On the TSC this can be accomplished in one of 2 ways. The first is by rotation of the Pechan prisms in the optical train. The second is by rotating the stages (the film itself). The desired effect -- stereo fusion -- is achieved in either way, but other problems develop if the Pechan prism is used.

If one optical train is rotated by the prism and the other left stationary, no semblance of stereo movement is possible. When the stages are moved, the pair will be moving in divergent directions. If both of the pair are rotated to some value not 0° or 180°, it is extremely difficult to predict movement of the stages; that is, the movement of the joystick in relation to that of the stages is not easily apparent.

ILLEGIB

For these reasons, the Pechan prism should not be used. Any rotation of the images, i.e. film, should be done by using the rotating stages. While this may seem unhandy at first glance, it will greatly speed the use of the instrument.

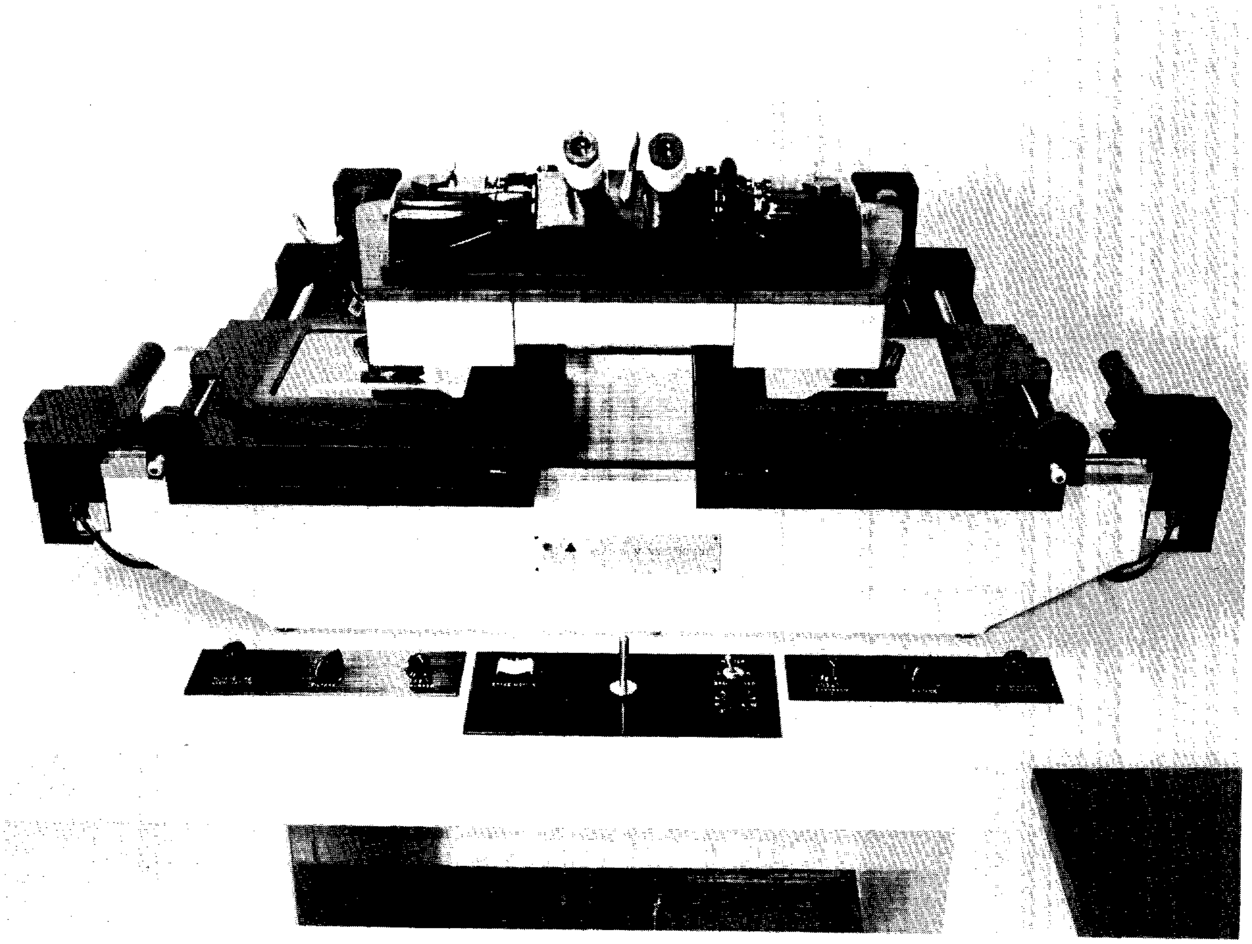
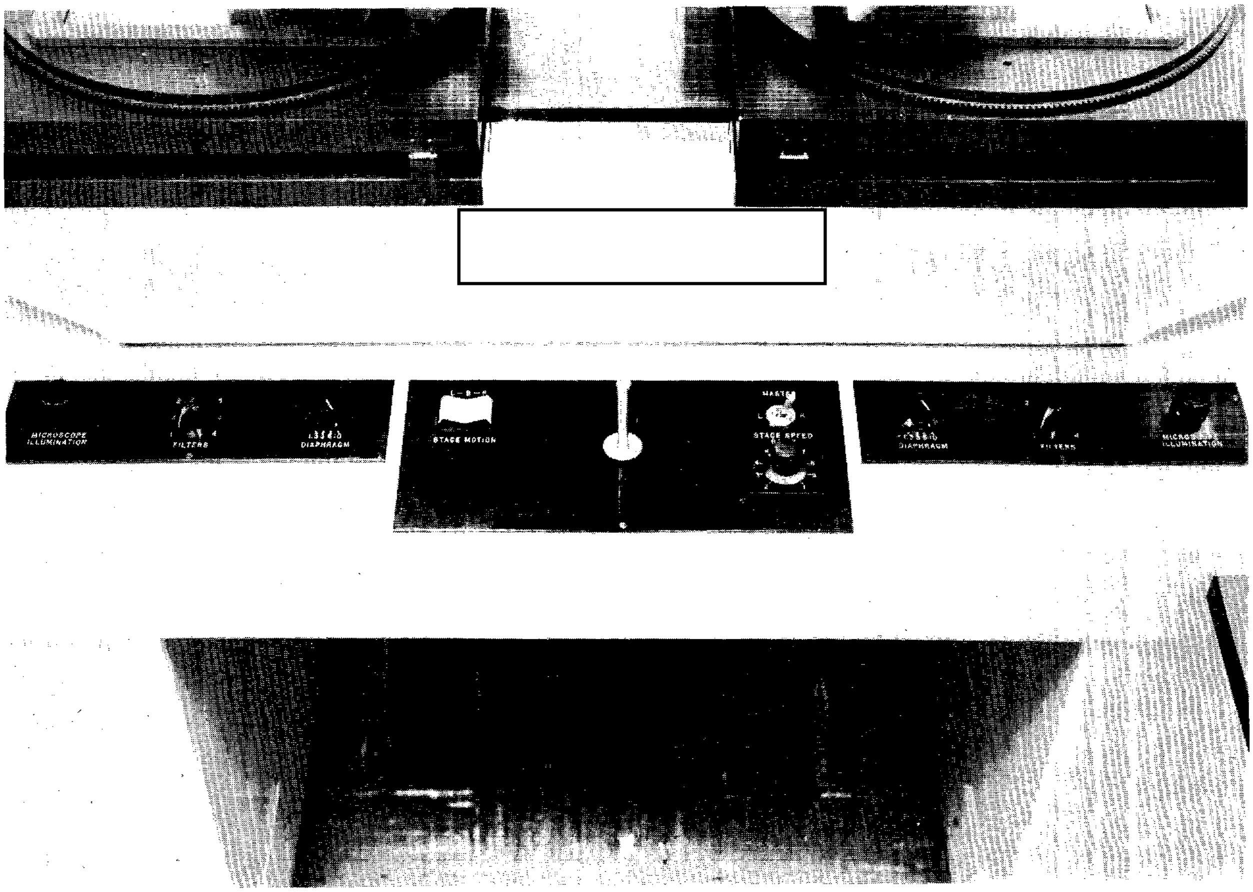


FIGURE 2. Front View from Operator's Position.



25X1

FIGURE 3. Stage Motion & Illumination Controls.

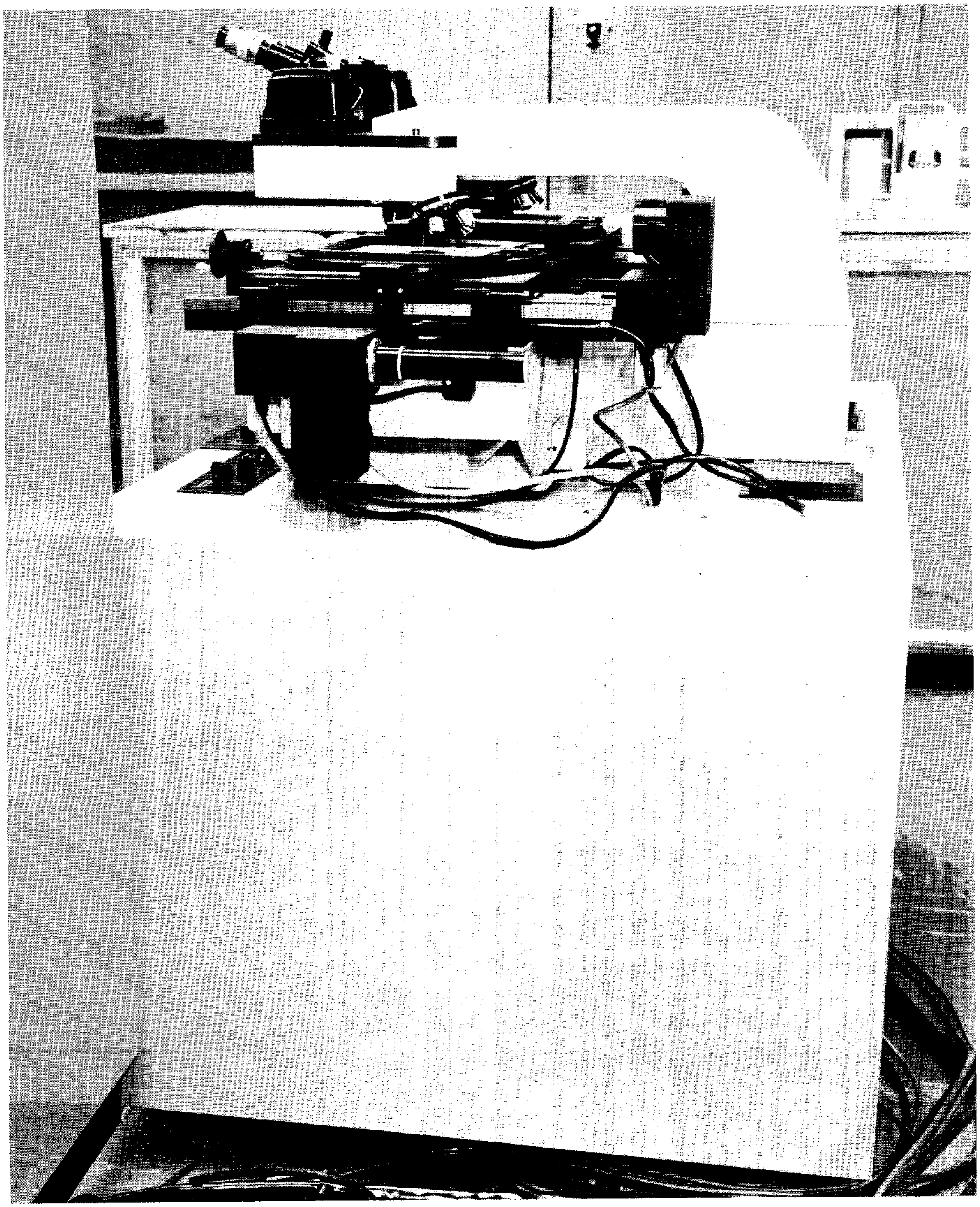
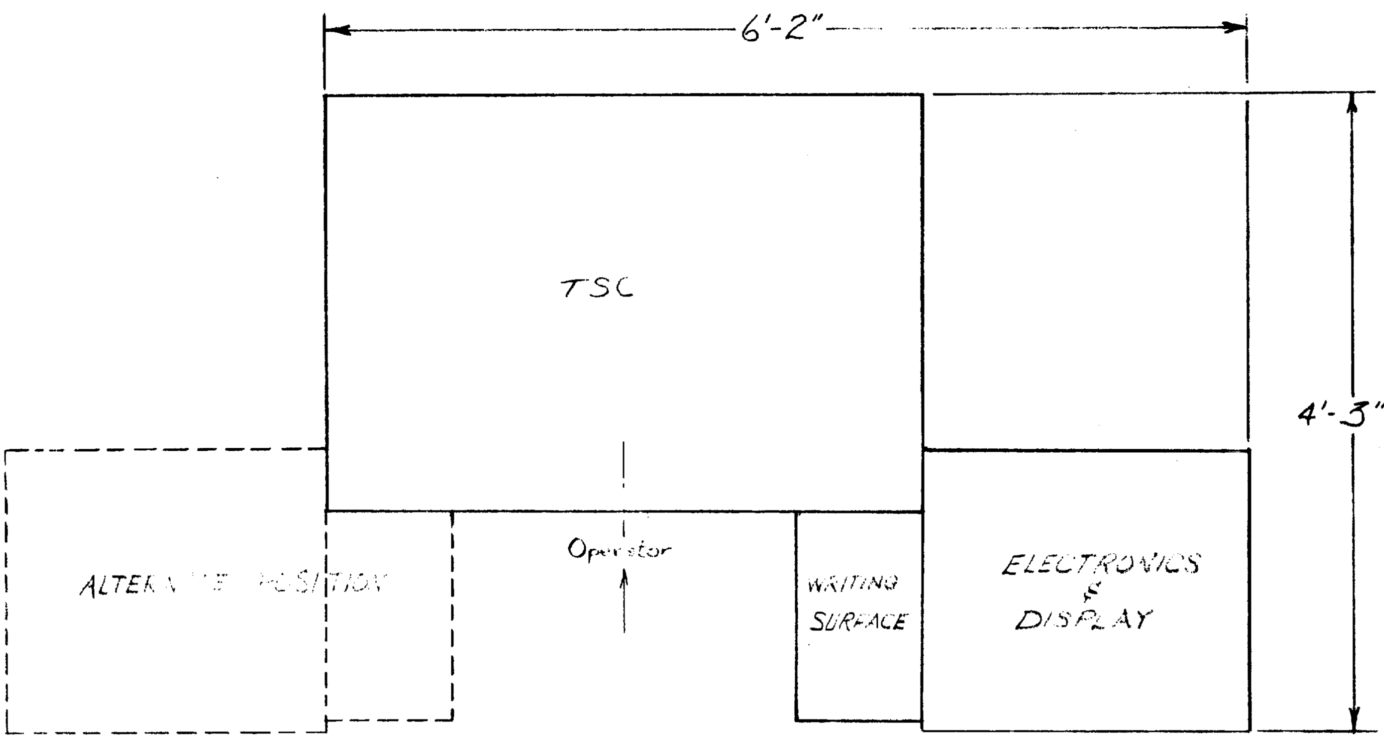


FIGURE 4. TSC -- Side View.

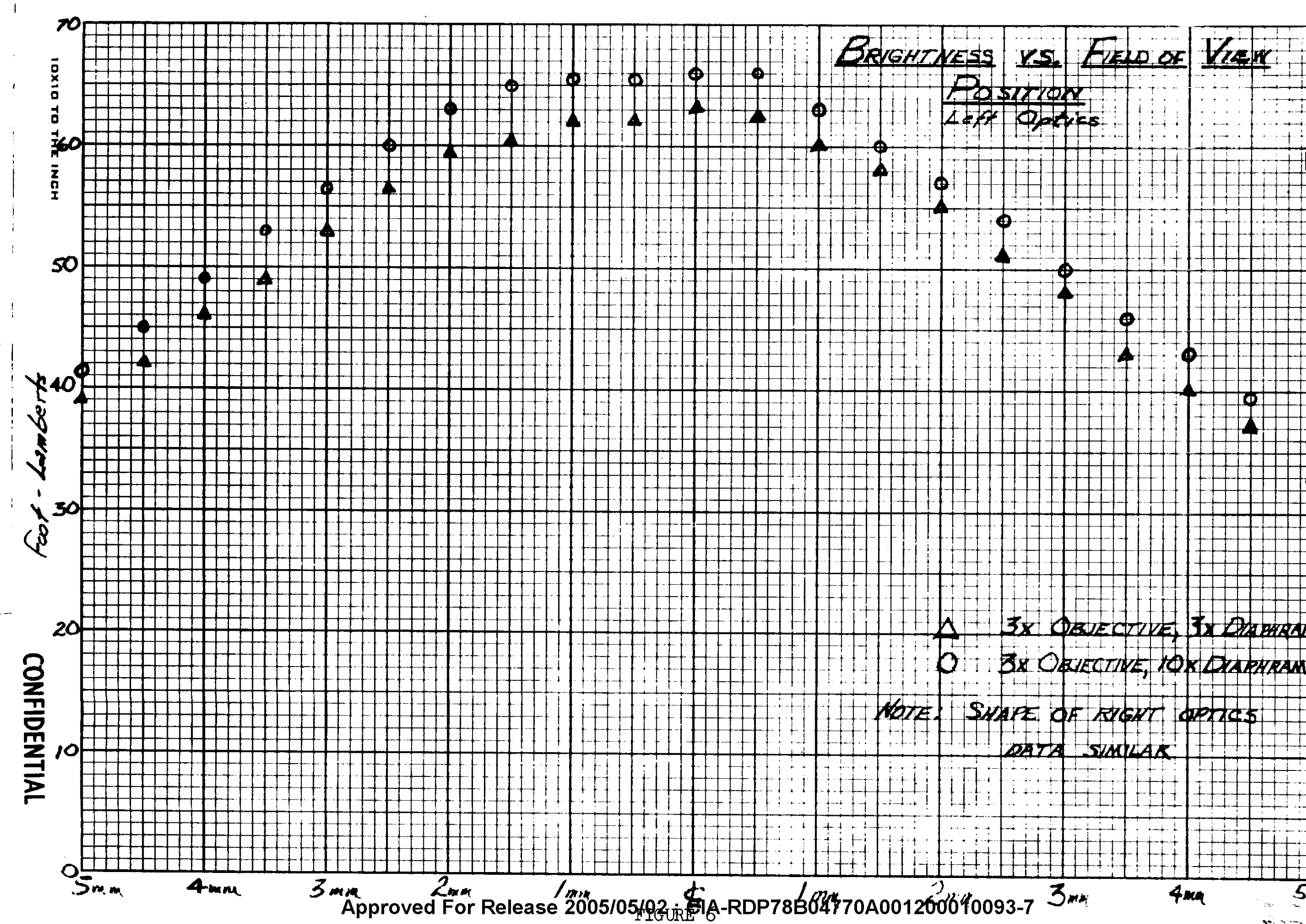
CONFIDENTIAL



CONFIDENTIAL

ALTERNATE TSC CONFIGURATION

FIGURE 5



ILLEGIB

CONFIDENTIAL

FIGURE 6

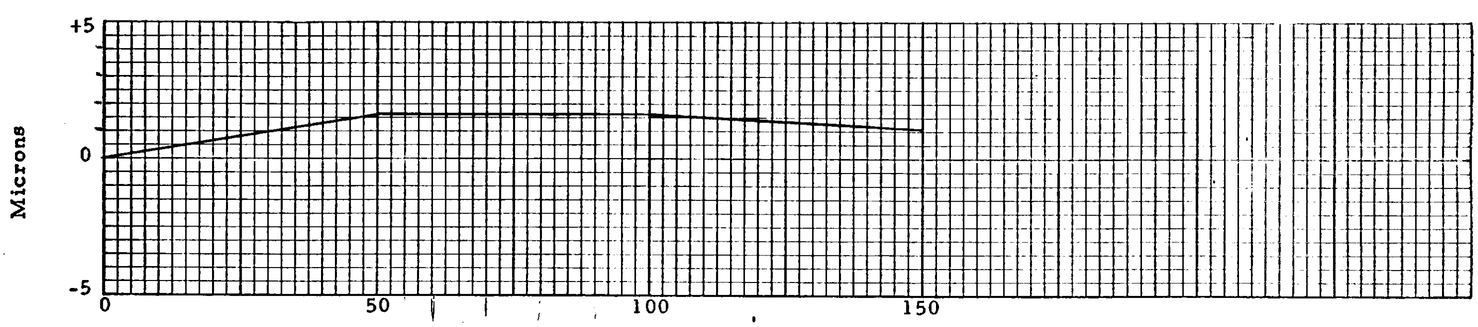
X AXIS CALIBRATION
(Left Stage)

Comparator	174001
Lead Screw	X (Left Stage)
Date	9/10/69
CC.	AGM
Standard	1656-150-CRI #3

* Curve indicates error at 68°F. Points on the curve which are above (+) or below (-) the "0" micron line indicate the amount actually greater or less than the distance traveled by the comparator stages than that indicated by the dial and scale readout system of the comparator.

25X1

25X1



X Axis Travel (MM)
(Left Stage)

25X1

CONFIDENTIAL

CONFIDENTIAL

FIGURE 7

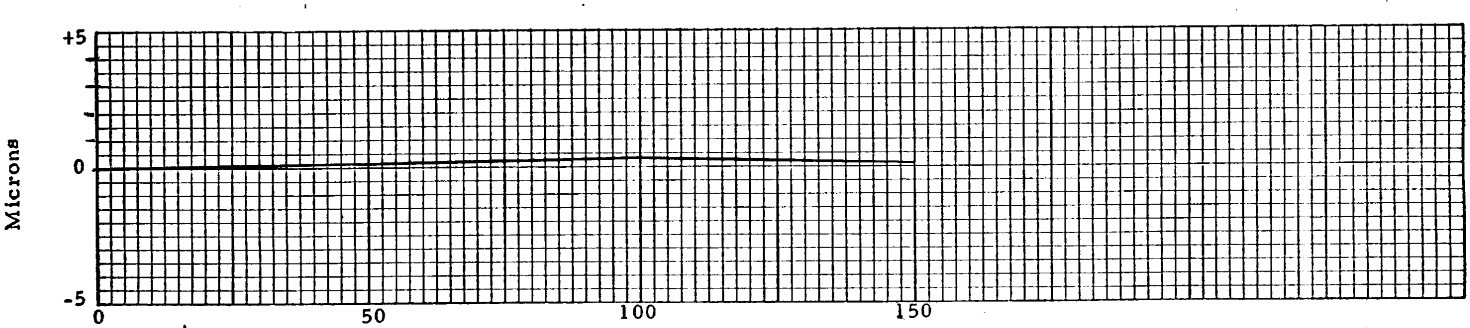
Y AXIS CALIBRATION
(Left Stage)

Comparator	174001
Lead Screw	Y (Left Stage)
Date	9/10/69
CC.	AGM
Standard	1656-150-CRI #3

* Curve indicates error at 68°F. Points on the curve which are above (+) or below (-) the "0" micron line indicate the amount actually greater or less than the distance traveled by the comparator stages than that indicated by the dial and scale readout system of the comparator.

25X1

25X1



Y Axis Travel (MM)
(Left Stage)

25X1

CONFIDENTIAL

CONFIDENTIAL

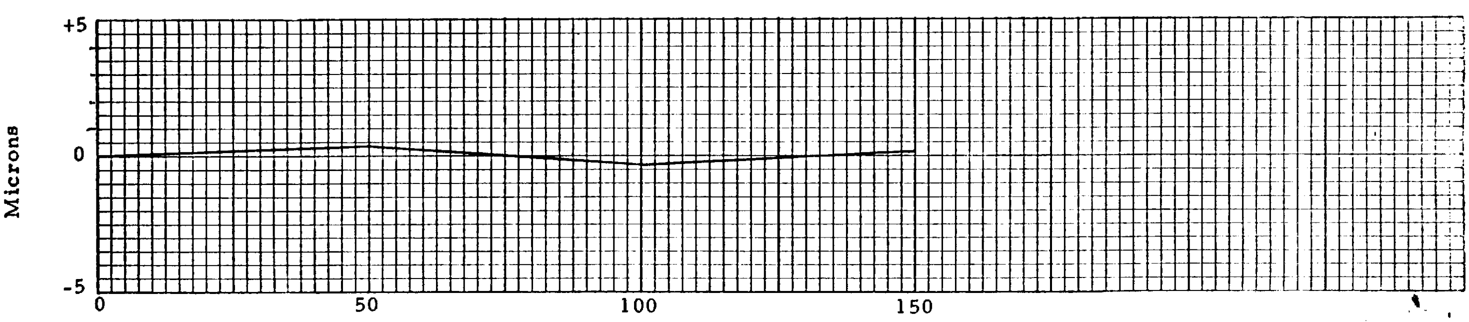
FIGURE 8

X AXIS CALIBRATION
(Right Stage)

Comparator	174001
Lead Screw	X (Right Stage)
Date	9/12/69
CC.	AGM
Standard	1656-150-CRI #3

* Curve indicates error at 68°F. Points on the curve which are above (+) or below (-) the "0" micron line indicate the amount actually greater or less than the distance traveled by the comparator stages than that indicated by the dial and scale readout system of the comparator.

25X1
25X1



X Axis Travel (MM)
(Right Stage)

25X1

CONFIDENTIAL

CONFIDENTIAL

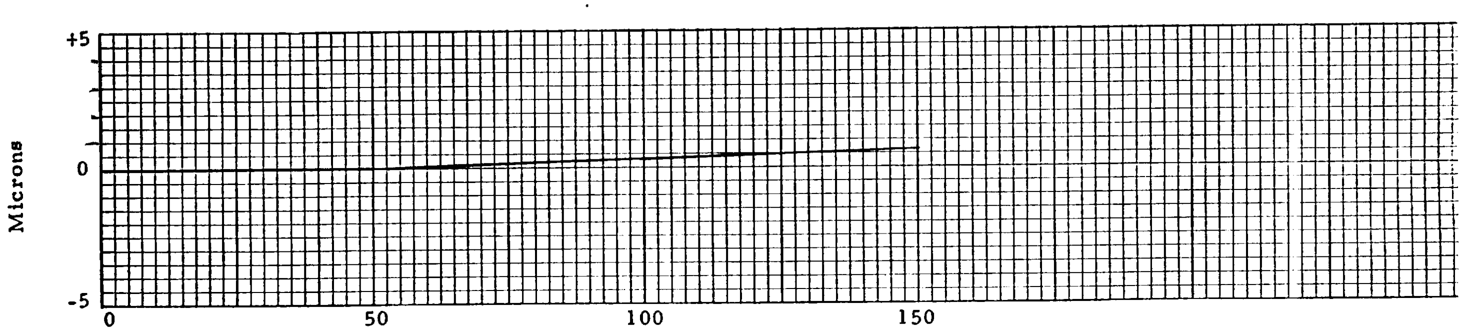
FIGURE 9

Y AXIS CALIBRATION
(Right Stage)

Comparator	174001
Lead Screw	Y (Right Stage)
Date	9/12/69
CC.	AGM
Standard	1656-150-CRI #3

* Curve indicates error at 68°F. Points on the curve which are above (+) or below (-) the "0" micron line indicate the amount actually greater or less than the distance traveled by the comparator stages than that indicated by the dial and scale readout system of the comparator. [redacted] 25X1

[redacted] 25X1



Y Axis Travel (MM)
(Right Stage)

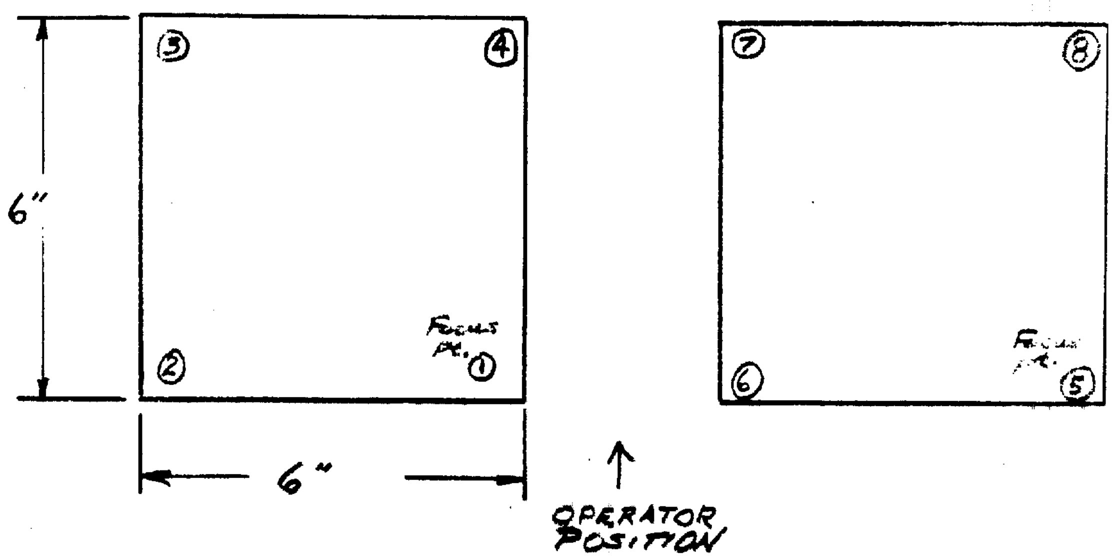
[redacted] 25X1

CONFIDENTIAL

CONFIDENTIAL

FIGURE 10

RESOLUTION AFTER STAGE TRANSLATION



Point	Reading (lines/mm)
1	854.4
2	537.6
3	854.4
4	854.4
5	760.8
6	760.8
7	Out of focus
8	604.8

Not called for in spec

FIGURE 11

TABLE 1

LUMINANCE AVAILABLE AT FILM PLANE

DIAPHRAM	FILTER	LEFT (Ft-1)	RIGHT (Ft-1)
10	1	28,500	22,500
6	1	27,000	20,750
3	1	23,000	15,500
1.3	1	15,000	10,000
10	2	7,200	6,100
10	3	3,525	2,900
10	4	1,020	800

1.4?

Filter Densities (calculated from luminance readings).

	Left		Right	% Difference
		nominal		
F 2	0.579		0.575	0.69
		indicated		
F 3	0.894	on 19.4	0.910	1.79
F 4	1.43		1.45	1.38

Note: 1) Readings made with bulbs with 0-4 hours use.
2) All readings made through ground glass with neutral density of 0.05.
3) Instrument used: Gamma Model 2020 Photometer with photomultiplier and fiber optics probe.

TABLE 2

RESOLUTION DATA

EYEPIECE	OBJECTIVE	ZOOM	SYSTEM POWER	LINES/MM LEFT PATH RESOLUTION	LINES/MM RIGHT PATH RESOLUTION
6X	1.3	1	7.8	67.44	67.44
		1.5	11.7	87.96	87.96
		2	15.6	134.60	120.0
	3	1	18	134.60	134.60
		1.5	27	169.68	190.96
		2	36	213.84	213.84
	6	1	36	268.8	268.8
		1.5	54	427.2	338.4
		2	72	480.0	427.2
	10	1	60	480.0	480.0
		1.5	90	604.8	537.6
		2	120	679.2	604.8
10	1.3	1	13	95.28	95.28
		1.5	19.5	120.0	106.80
		2	26	120.0	120.0
	3	1	30	213.84	213.84
		1.5	45	240.0	240.0
		2	60	268.8	240.0
	6	1	60	427.2	338.4
		1.5	90	480.0	480.0
		2	120	537.6	480.0
	10	1	100	604.8	604.8
		1.5	150	760.8	679.2
		2	200	854.4	760.8

TABLE 3

FIELD OF VIEW MEASUREMENTS

Eyepiece	Obj. Lens	Specified FOV(mm)	Left FOV (mm) X Dir	Left FOV (mm) Y Dir	Right FOV (mm) X Dir	Right FOV (mm) Y Dir
6	1.3	14.0	11.27	11.38	11.33	10.98
6	3	6.0	5.32	5.34	5.11	5.05
6	6	3.0	2.62	2.61	2.51	2.49
6	10	1.8	1.58	1.58	1.54	1.53
10	1.3	14.0	11.47	11.45	11.11	11.07
10	3	6.0	5.44	5.38	5.13	5.11
10	6	3.0	2.62	2.64	2.53	2.53
10	10	1.8	1.59	1.60	1.55	1.55

APPENDIX

D.W. MANN TWIN STAGE ON-LINE PI COMPARATOR
ACCEPTANCE TEST CHECK LIST

I. Material to be furnished with instrument:

25X1

1) 2 ea [redacted] Fluotar (5100) - 3.0x Objective Lenses

2) 2 ea " " (5105) - 6.0x " "

3) 2 ea " " (5050) - 10.0x " "

4) 2 ea " Compensating (5551) - 6x Eyepieces

5) 2 ea " " (5383) - 10x "

6) 1 ea Operator's Instruction Manual

7) 1 ea Maintenance Manual (including Schematics)

8) 1 ea Spare Parts List

II. Physical Dimensions

1) Length 48" max

2) Width 34" max

3) Knee Well Height 25" min

4) " " Width 24" min

5) " " Depth 22" min

6) Eyepoint from floor 47 3/4" ± 1"

III. Visual Observations

1) Warning light when power is on ✓

2) Limit switches at ends of stage travel

Left Stage +X		✓
"	-X	✓
"	+Y	✓
"	-Y	✓
Right Stage +X		✓
"	-X	✓
"	+Y	✓
"	-Y	✓

3) Spares for all fuses ✓

4) Markings on all controls ✓

5) No visible flicker on full stage illumination ✓

6) Separate controls for left & right optics illumination ✓

7) Electronic Console on casters ✓

8) Ready access to a) stage lighting ✓

b) electronics ✓

9) Check for sharp corners

a) TSC ✓

b) Console ✓

IV. Stage Drive

1) Single joystick control for

a) both stages ✓

b) left stage ✓

c) right stage ✓

2) Speed variability

a) 5 µm/sec max min left stage ✓

right stage ✓

b) 5 mm/sec min max left stage ✓

right stage ✓

3) Differential Motion 5/1 min

4.6.2

left/right ✓

right/left ✓

4) Controls smooth and positive ✓

5) Total motion 6 in min (152.4 mm)	a) left stage, X	✓
	Y	✓
	b) right stage X	
	Y	✓
6) Rotary motion 360°	a) left stage	✓
	b) right stage	✓
7) Least count digitizer 1 µm		✓
8) Glass pressure plate .063 thick max		✓
9) Focus sharp @ 200X over 1 in square, Left leg		✓
Right leg		✓

V. Illumination

1) Condenser type source under each objective	✓
2) Variability 50% to 100% full intensity	

VI. Optics

1) Independent fine focus for each leg	
2) Sharp round black reticle on 20 µm in diameter in each leg of optics	

4) Resolution (85% of unmodified system) both legs

.85 × 960 = 817 l/mm @ 200X

817 lines/mm min ✓

VII. Electronics & Computer Interface

1) All words sending in proper order ✓

2) Acknowledge transmission received okay ✓

3) Errors timed out per change ✓

4) Echo returned on-line ✓

DISTRIBUTION

Activity	No. Copies
NPIC/PSG/RRD/DB	1
NPIC/TSSG/PPS (through Ch/TSSG)	1
NPIC/TSSG/RED/Ch	1
NPIC/TSSG/RED/Project Officer	1
NPIC/IEG/OSS	1
DDI/IAS/Tech. Adv.	1
DIA/DIAAP-9/Tech & Dev. Br.	1
ARMY/SPAD/PSO	1
EXRAND (through NPIC Member, [redacted]	8
NPIC/TSSG/ESD	5

25X1

CONTROL TECHNIQUE	CONTROL TYPE: JOYSTICK	CONTROL TYPE: TRACKBALL
POSITION CONTROL 1:76,200 resolution required Best for fine positioning	CANNOT MEET RESOLUTION REQ'TS	FEASIBLE, ALTHOUGH RESOLUTION OF OFF THE SHELF COMPONENTS MAY NOT BE ADEQUATE. (LARGE BALL DIAMETER IS REQUIRED)
RATE CONTROL Accuracy 2µ RATES { 5µ/sec min, 5000µ/sec max Best for coarse positioning – Accuracy vs min rate requires less than 1/2 sec reaction by operator.	STANDARD TECHNIQUE - PROBLEM WITH ZERO POSITION DETENT VS DEADZONE. FIXED POSITION (FORCE) STICK ELIMINATES THIS PROBLEM. - COMPENSATION FOR MAGNIFICATION LEVEL IS DESIRABLE	REQUIRES A NULLING CAPABILITY THAT COMPLICATES CONTROL OPERATION. CAN BE SPRING LOADED BUT PROBLEM REDUCES TO MINIMUM LENGTH JOYSTICK.
RATE AIDED POSITION CONTROL	DOES NOT SOLVE RESOLUTION PROBLEM	MORE EFFECTIVE FOR THIS APPLICATION THAN PURE POSITION CONTROL BUT RESOLUTION MAY STILL BE A PROBLEM
DUAL MODE CONTROL (RATE AND POSITION) Rate control used for coarse positioning - position control for final adjustments	SATISFACTORY SOLUTION · MODE SWITCHING CONTROL CAN BE MOUNTED ON THE STICK OR CAN BE POSITIONED INDEXED. - FIXED POSITION STICK IS PREFERRED TO [illegible] STICK, [illegible] IF SPACE IS A PROBLEM	PREFERRED SOLUTION IF A SINGLE CONTROL MUST BE USED. ~~MAY BE [illegible] JOYSTICK FOR COARSE POSITIONING OVER~~ MODE SWITCHING CONTROL MUST ACT TO NULL RATE

References

- Gibbs, C. B. & Baker, J. C. "Free-moving versus fixed control levers in a manual tracking task" APU 161/51, Applied Psych Res Unit. Medical Research Council, Cambridge, England, 1951

- Tustin, A. (Ed). "Automatic and Manual Control" London, Butterworths, 1952.

- Andreas, B.G.; Murphy D.P. & Spragg, S.D.S, "Speed of Target Acquisition as Functions of Knob vs. Stick Control, Positioning vs Velocity Relationships and Scoring Tolerance," Rochester, New York, Univ. of Rochester, Scientific Report No 3, 1955, AD 76 207.

- Birmingham, H.P., "Comparison of a Pressure and Moving Joystick." Naval Research Laboratory, Washington, D.C. Interim Report, S-3600-330A/50 rac, September 6, 1950.

- Reed, J.D., "Design of Controls for Positioning a Marker Quickly and Accurately" USAF Rome Air Development Command Progress Report No. 1, 1953, AD 22 407

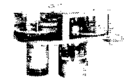
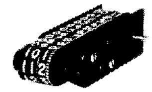
— Spangler, R. S. "Evaluation of track stick versus track ball" U. S. Army Air Defense Board NR TF-2160, March 1961, AD 253 568.

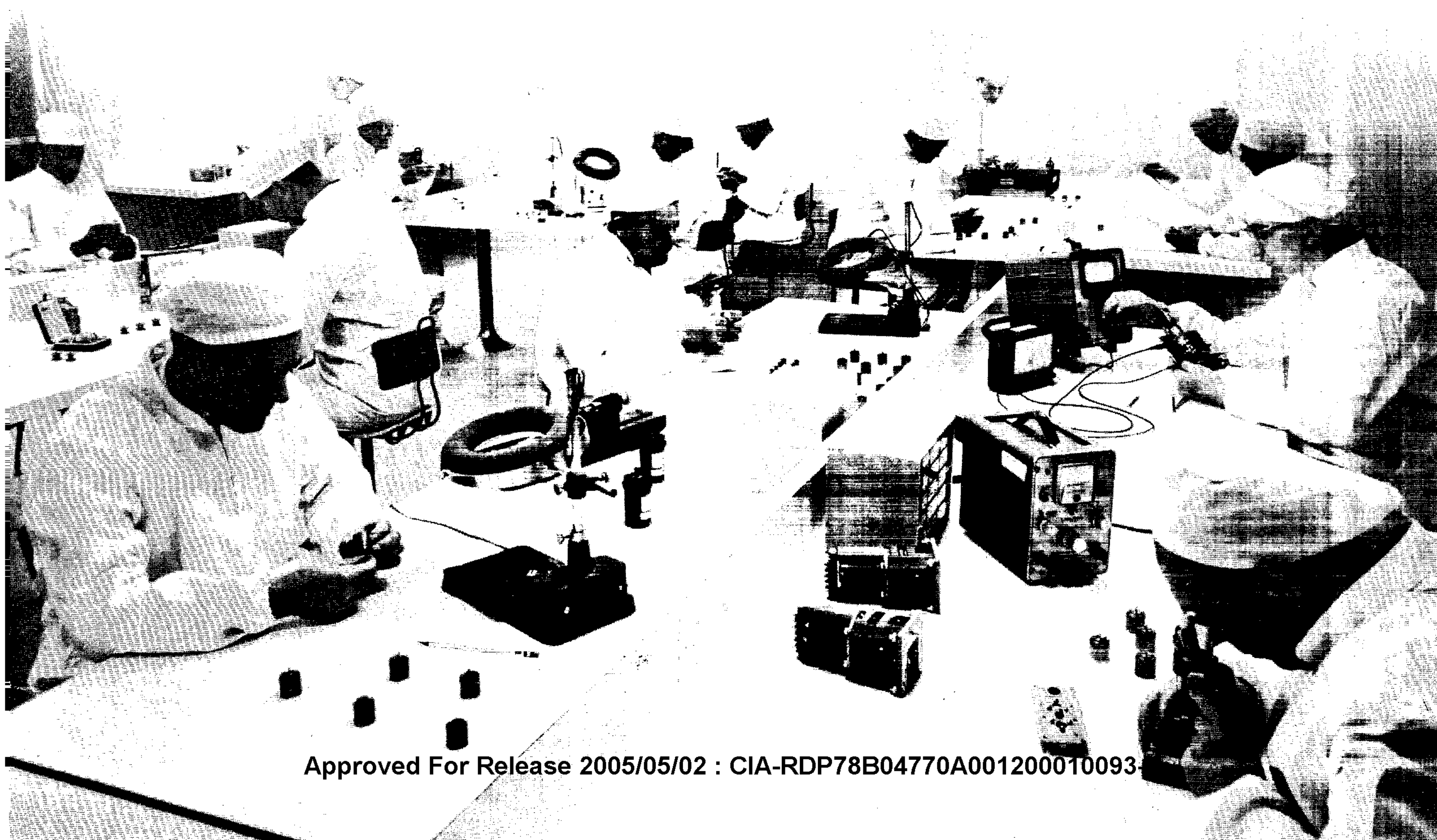
— Thorton, G. B., "A Comparison of an Experimental Rolling Ball Control & a Conventional Joystick in Speed of Tracking on a Simulated Radar Display". Canada: Canadian Defense Res. Med. Lab. Report 107-1, 1953, AD 40 385,

Orbit Instrument Corporation

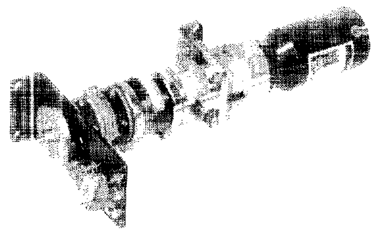


SERVO INSTRUMENTATION, ASSEMBLIES, COUNTERS, DESIGN AND DEVELOPMENT. PRECISION ENGINEERED SERVOS FOR AIRCRAFT, GROUND AND SHIPBOARD ENVIRONMENT, DESIGNED TO MEET THE EXACTING NEEDS OF OUR SPACE AGE.

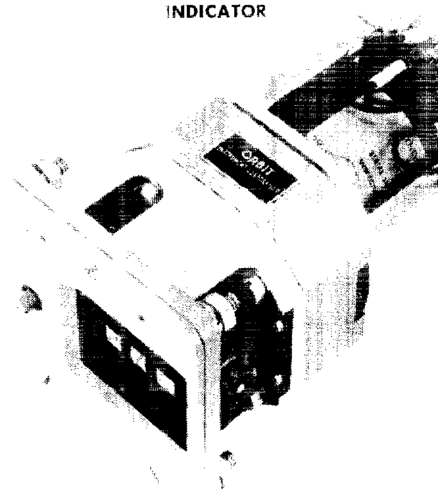



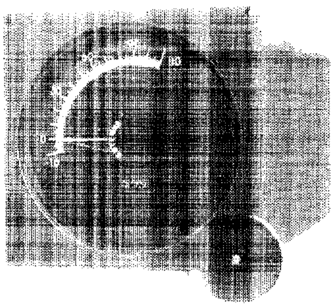



IN-LINE SERVO ASSEMBLY

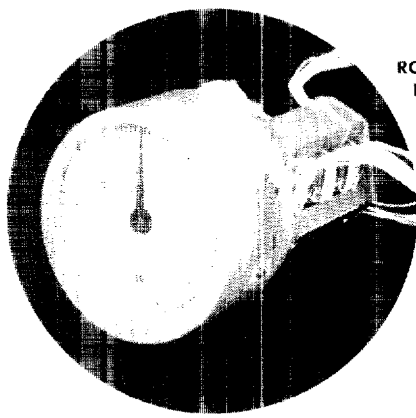


DIGITAL BEARING INDICATOR

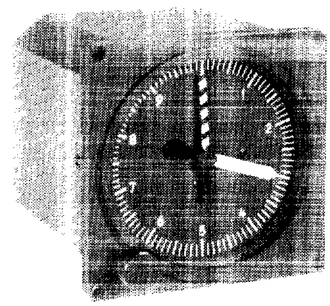




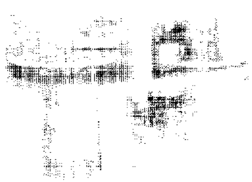
MANUAL-ORDERED ELEVATION INDICATOR



ROD POSITION INDICATOR



SYNCHRO TORQUE RECEIVER INDICATOR

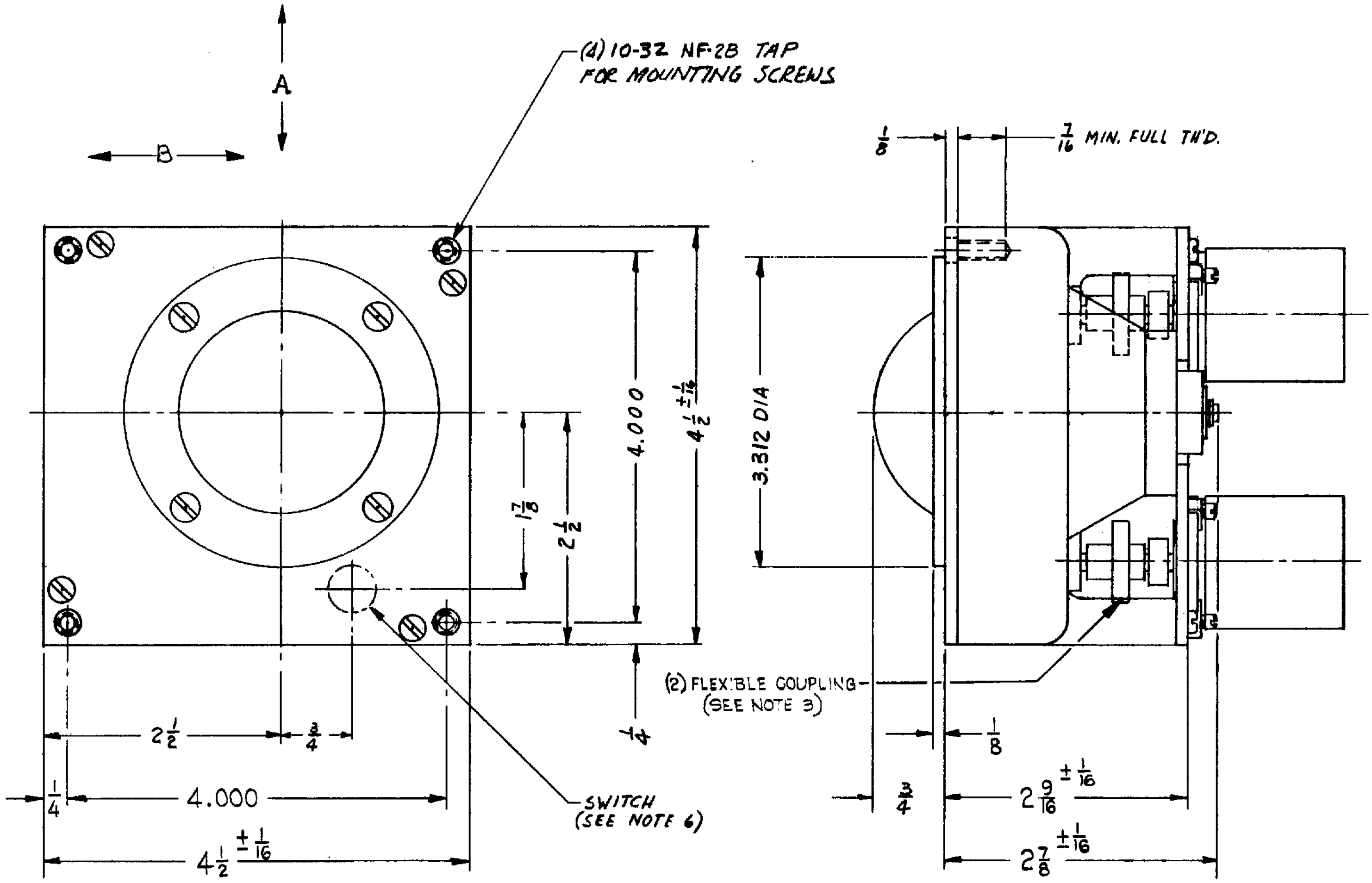


SERVO ASSEMBLY

QUALITY, RELIABILITY, EXPERIENCE, SERVICE . . .

In Orbit Instrument Corporation's modern facility of 15,000 square feet, Orbit personnel supply industry with precision servo assemblies and servo instruments. The establishment of a Quality Assurance program, in accordance with MIL-Q-9858 and a class III white room, insures quality servo instruments.

Orbit's facilities are devoted exclusively to the production of reliable space age electro-mechanical assemblies and instruments.



NOTES:

1. SPEED RANGE: ONE REVOLUTION OF BALL WILL ROTATE THE "A & B" COMPONENTS NOMINALLY 1.5 REVOLUTIONS (WITH FIXED ADJUSTMENT FROM 1.35 TO 2.0 REV'S.)
2. COMPONENTS "A & B" ARE SIZE 15. UNIT CAN BE ADAPTED FOR SMALLER COMPONENTS HOWEVER, LARGER ONES WILL REQUIRE AN ENLARGED COMPONENT MTG. PLATE.
3. THIS IS A FLEXIBLE COUPLING WITH SPLIT HUB USED TO CONNECT TO COMPONENTS "A & B".
4. WEIGHT OF UNIT = 2.2 LBS. EXCLUSIVE OF ALL ELECTRICAL COMPONENTS.
5. ENVIRONMENTAL: UNIT DESIGNED TO MEET THE REQUIREMENTS OF MIL-E-5400 & MIL-E-16400.
6. A MOMENTARY PUSH SWITCH CAN BE ADDED, IF NECESSARY, IN LOCATION INDICATED.

ORBIT X-Y BALL TRACKER
TYPE 451

DEC. 1966

Approved For Release 2005/05/02 : CIA-RDP78B04770A001200010093-7

ORBIT X-Y BALL TRACKER TYPE 451

Orbit X-Y Ball Trackers are utilized as manual inputs to various navigation, radar display and control systems. The units are designed to clamp into the control panel of the system with only the ball and surrounding collar protruding.

Rotation of the ball about any axis which lies in the plane of the control panel is resolved into its "X" & "Y" components. Friction discs and infinite resolution couplings transmit the poistion to the system through digital encoders, synchros or potentiometers. The ball will remain in this position until displaced further by the operator.

An enable push button and spring return mechanism which return the components to the start position can be supplied.

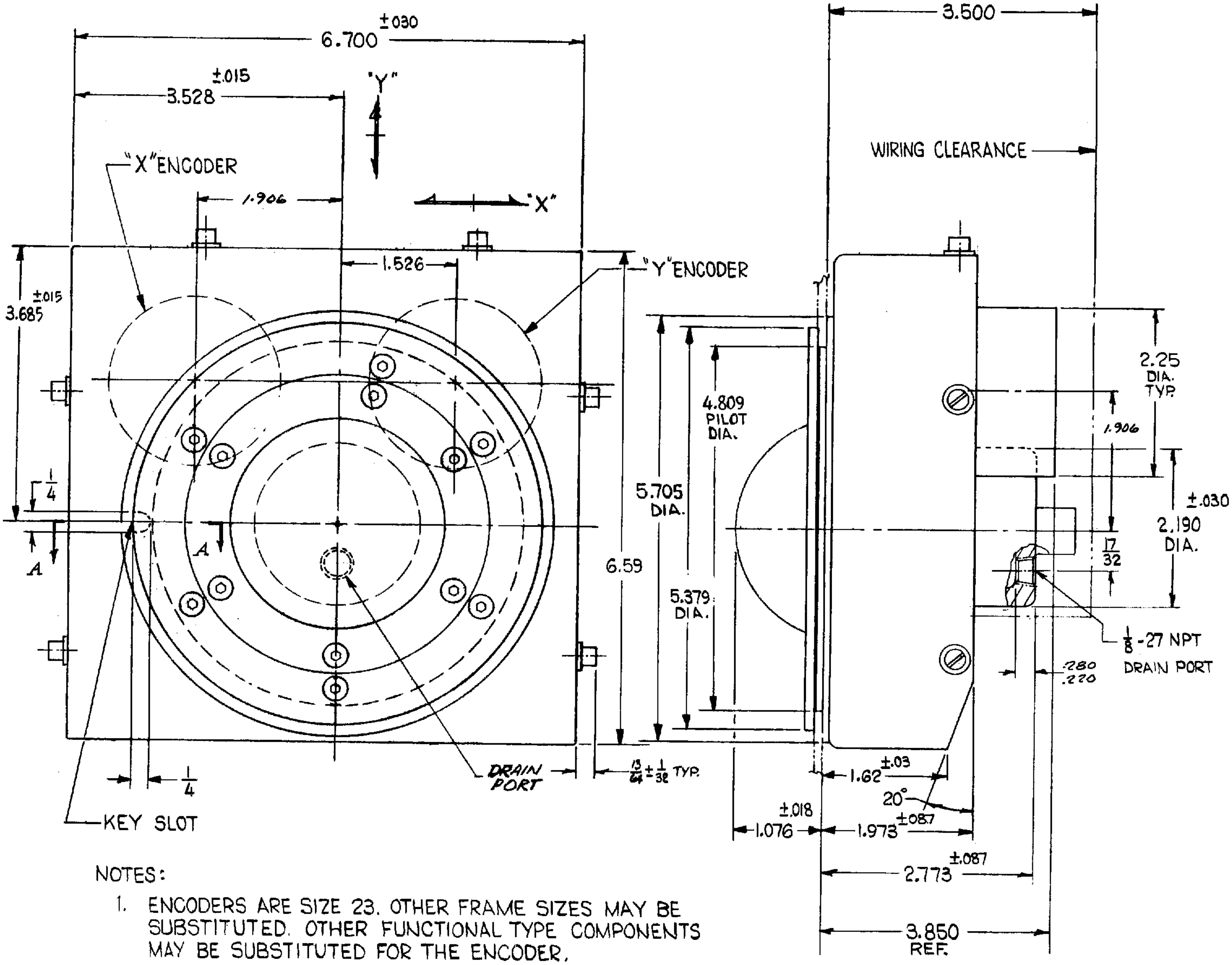
The phenalic composition ball is 2.500" in diameter with 5/8" protruding above the mounting surface.

The tracking force necessary to rotate the ball is approximately 3 oz.

All castings and brackets are anodized aluminum alloy and all shafts and bearings are corrosion resistant steel.

When mounted on an approximately horizontal panel, with a suitable ring gasket between the mounting surface and panel, the unit is drip-proof. For applications not requiring drip-proofing, the seal can be removed which results in a tracking force of less than 1 oz.

For further information regarding specific applications, contact Orbit Instrument Corp., 131 Eileen Way, Syosset, New York.



NOTES:

1. ENCODERS ARE SIZE 23. OTHER FRAME SIZES MAY BE SUBSTITUTED. OTHER FUNCTIONAL TYPE COMPONENTS MAY BE SUBSTITUTED FOR THE ENCODER.
2. SPEED RANGE: ONE REVOLUTION OF BALL WILL ROTATE THE 'X & Y' ENCODERS NOMINALLY 1.65 REVOLUTIONS. (WITH FIXED ADJUSTMENT FROM 1.15 REV. TO 2.5 REV.
3. ENVIRONMENTAL: DESIGNED TO MEET VIBRATION (MIL-STD-167) & SHOCK (MIL-S-901) OF MIL-E-16400.
4. WEIGHT OF UNIT: 4.9 LBS. INCLUSIVE OF ALL ELECTRICAL COMPONENTS.

DEC. 1966

ORBIT X-Y BALL TRACKER TYPE 651

ORBIT X-Y BALL TRACKER TYPE 651

Orbit X-Y Ball Trackers are utilized as manual inputs to various navigation, radar display and control systems. The units are designed to clamp into the control panel of the system with only the ball and surrounding collar protruding.

Rotation of the ball about any axis which lies in the plane of the control panel is resolved into its "X" & "Y" components. Friction discs and infinite resolution couplings transmit the position to the system through digital encoders, synchros or potentiometers. The ball will remain in this position until displaced further by the operator.

The unit is shown with (2) size 23 magnetic incremental encoders.

An enable push button and spring return mechanism which return the components to the start position can be supplied.

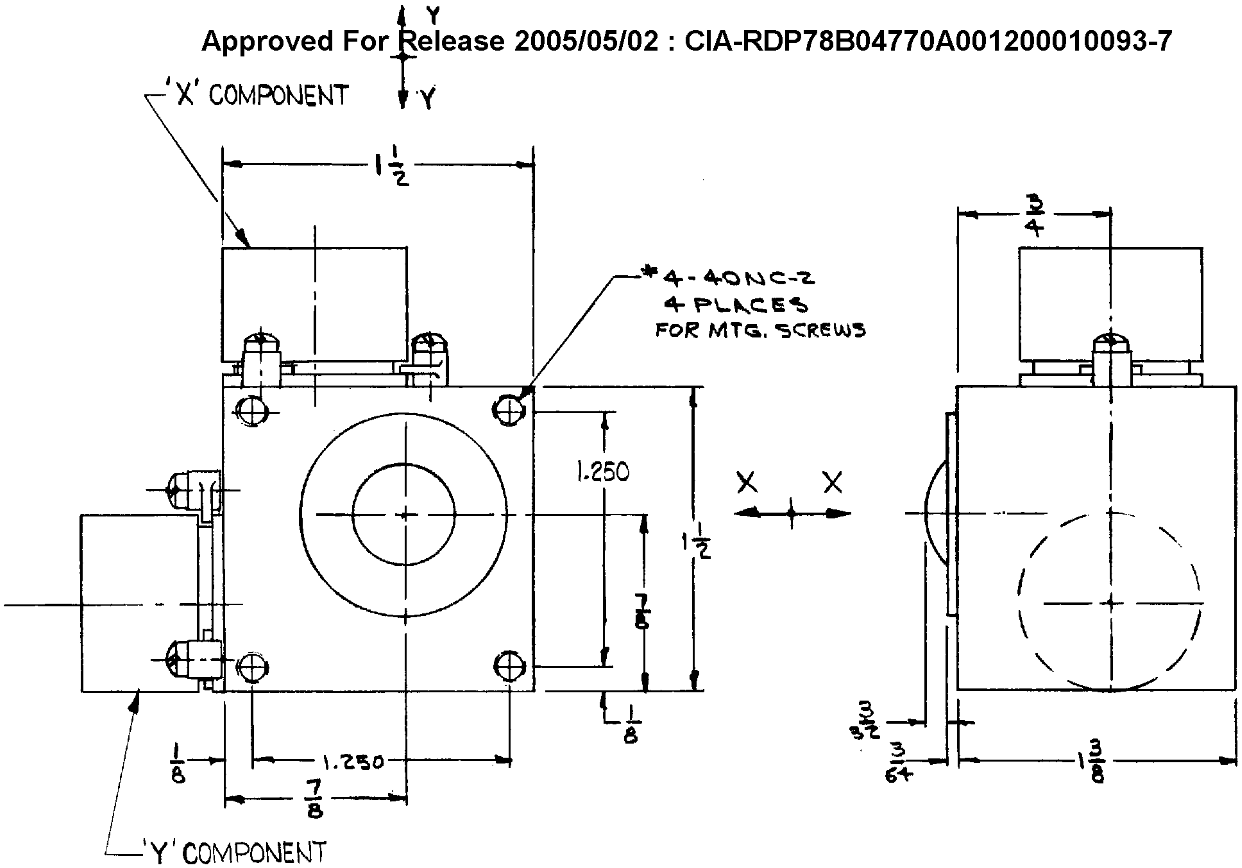
The phenalic composition ball is 3.100" in diameter with 13/16" protruding above the mounting surface.

The tracking force necessary to rotate the ball is approximately 3 oz.

All castings and brackets are anodized aluminum alloy and all shafts and bearings are corrosion resistant steel.

When mounted on an approximately horizontal panel, with a suitable ring gasket between the mounting surface and panel, the unit is drip-proof. For applications not requiring drip-proofing, the seal can be removed which results in a tracking force of less than 1 oz.

For further information regarding specific applications, contact Orbit Instrument Corp., 131 Eileen Way, Syosset, New York.



NOTES:

1. ONE REVOLUTION OF BALL WILL ROTATE THE 'X' & 'Y' COMPONENTS 1.0 REVOLUTION
2. COMPONENTS 'X' & 'Y' ARE .875 DIA. X .687 LG
3. WEIGHT OF UNIT: 5.0 OUNCES EXCLUSIVE OF ELEC. COMP.
   1.2 OUNCES APPROX. ELEC. COMP.
4. ENVIRONMENTAL: UNIT DESIGNED TO MEET THE REQUIREMENTS OF MIL-E-5400 & MIL-E-16400

ORBIT X-Y BALL TRACKER
TYPE [illegible]

DEC. 1966

ORBIT X-Y BALL TRACKER TYPE 151

Orbit X-Y Ball Trackers are utilized as manual inputs to various navigation, radar display and control systems. The units are designed to clamp into the control panel of the system with only the ball and surrounding collar protruding.

Rotation of the ball about any axis which lies in the plane of the control panel is resolved into its "X" & "Y" components. Friction discs and infinite resolution couplings transmit the position to the system through digital encoders, synchros or potentiometers. The ball will remain in this position until displaced further by the operator.

The phenalic composition ball is .750" in diameter with 3/32" protruding above the mounting surface.

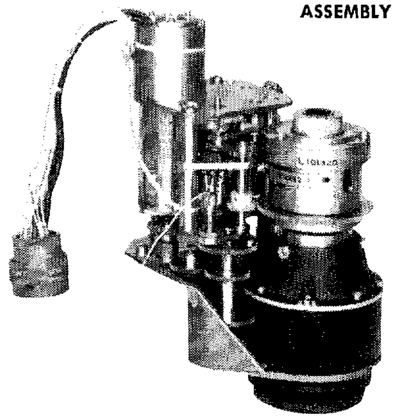
The tracking force necessary to rotate the ball is approximately 1 oz.

All castings and brackets are anodized aluminum alloy and all shafts and bearings are corrosion resistant steel.

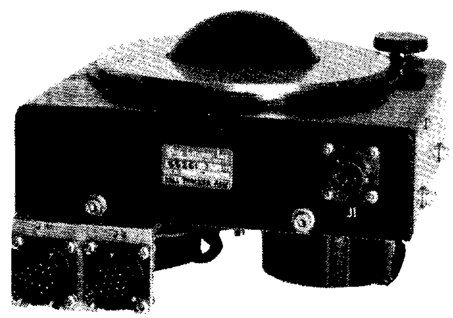
When mounted on an approximately horizontal panel, with a suitable ring gasket between the mounting surface and panel, the unit is drip-proof. For applications not requiring drip-proofing, the seal can be removed which results in a tracking force of less than 1 oz.

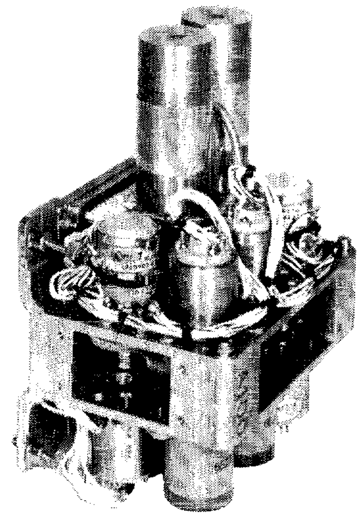
For further information regarding specific applications, contact Orbit Instrument Corp., 131 Eileen Way, Syosset, New York.

OPTICAL TRACKER
ASSEMBLY

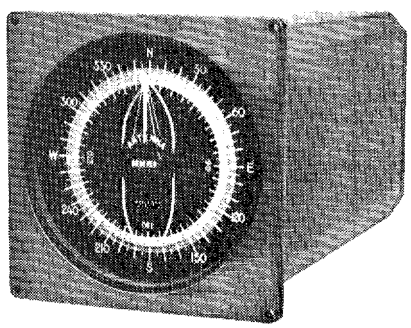


X-Y BALL TRACKER



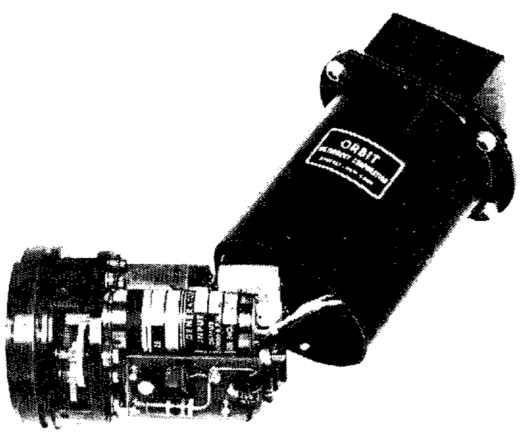


INTEGRATING SERVO
PRECISION OUTPUTS



TRIPLE DISPLAY ANTENNA
BEARING INDICATOR

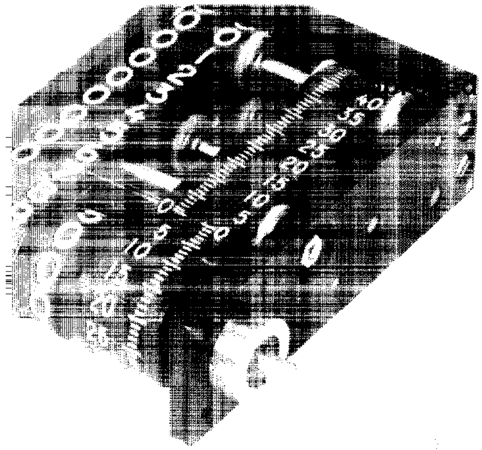
We at Orbit Instrument Corporation specialize in the design, development and production of servo instruments, servo assemblies, electro-mechanical packages, in-line servos, ball trackers, precision instrument counters, precision gear trains and gearheads, magnetic brakes and clutches, differentials. Our representatives and engineers stand ready to meet any special requirements you might have.

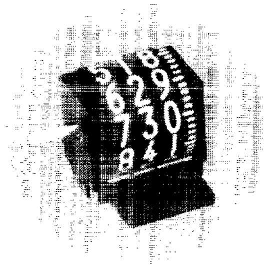


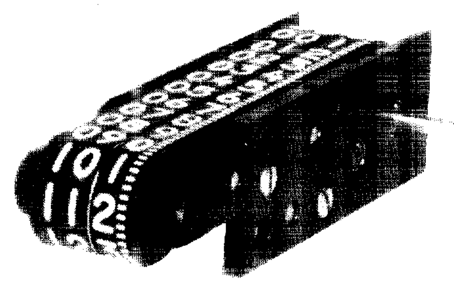
POSITION SERVO

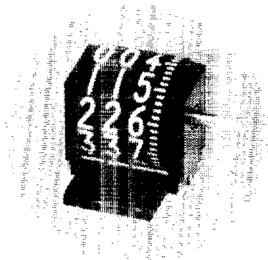
Orbit

INSTRUMENT CORPORATION
131 EILEEN WAY
SYOSSET, LONG ISLAND, N. Y. 11791
Telephone 516-921-6310

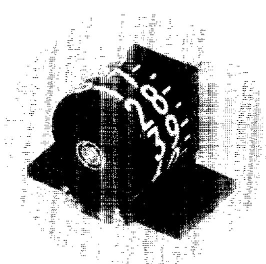








Low torque-high speed applications, drum and tape displays, bearing counters, standard counters, custom designed counters. Many options are available. They include right or left hand shaft, shaft length and diameter, and mounting provisions to suit individual installation. Information concerning custom configurations available on request.



Orbit INSTRUMENT CORPORATION 131 EILEEN WAY • SYOSSET, LONG ISLAND, N. Y. 11791
516-721-6310

PIP INDICATION WITH THE JOYSTICK AND THE ROLLING BALL

Although joystick controls have been employed for a number of years to control strobes for designating pips, surprisingly few experimental data have been reported in the radar literature (though there are numerous studies in the psychological literature on tracking behaviour).

A study of pip tracking behaviour by Thornton (1954a) is of some interest in this regard because it reports a comparison of a positional joystick control with what we believe to be the only available data obtained with a rolling ball control. The display was a 12 in. CRT on which a series of 25 pips

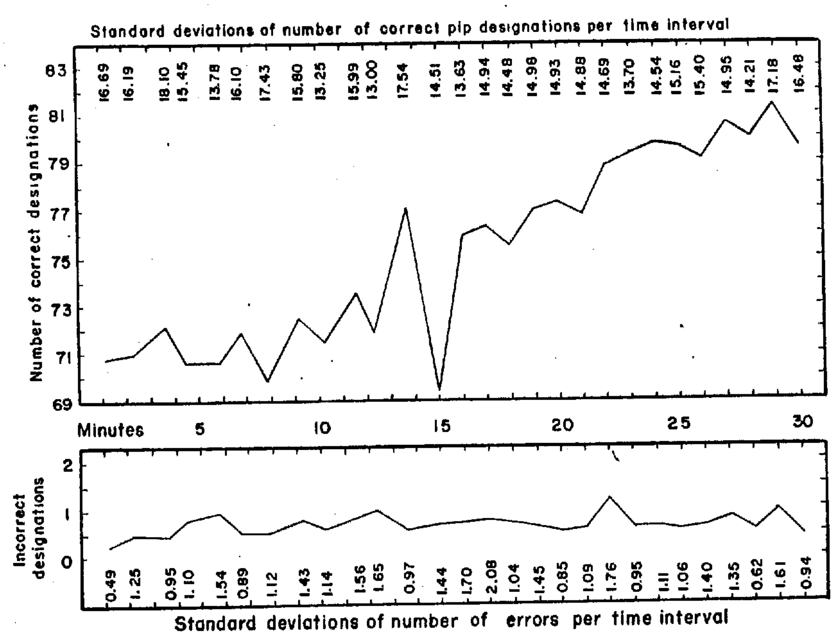


Fig. 103. Correct and "error" designations and time using the pencil indicator

located in any required size of pattern could be made to appear in immediate succession by depressing a microswitch held in the non-preferred hand.

The joystick control was a 6 in. stick mounted in a horizontal plane directly in front of the center of the tilted display. Forty-five degrees of stick displacement resulted in 5 in of strobe displacement (in the same direction). The rolling ball control, which was interchangeable with the stick displacement resulted in 5 in. of strobe displacement (in the same suspended on an air bearing. The ball protruded $1\frac{1}{2}$ in. above the top of the cup, the exposed portion providing the control surface manipulated by the palm or finger of the hand. One complete revolution of the ball resulted in $2\frac{1}{2}$ in. of strobe displacement.*

* The rolling ball possesses several engineering merits, e.g. small wheels can be friction driven by the concealed portion of the ball. By boring many holes near the wheel circumference, providing a light source on one side and a light sensitive cell on the other, the rolling ball can generate digital information concerning position.

The task was to designate a pip with the strobe, press the switch to have the pip disappear and a new one appear, designate the new pip, and so on. The distance through which the strobe had to be moved for successive pip designation ranged from 1 to 14 cm. Data in Fig. 102 show that in general the greater strobe movement the greater the average designation time per pip. Of greater concern, however, is the finding that for very short strobe movements there was no difference between the two controls, but for movements of 5 cm or more shorter designation times were obtained with the joystick. The dependence of this finding upon the display control ratio has not been investigated, but may be of importance. In general we conclude that the ball is as efficient as the joystick in terms of the time per designation in situations where pip positions need successive though slight amendments. For greater amendments the joystick is superior. On the average about 21 pips per min can be designated with the ball and about 25 with the joystick.

An interesting feature of Thornton's study is that of the 12 subjects who used the ball first, all preferred the ball to the joystick. Of the 12 who used the joystick first, 11 preferred the joystick. There were no sex differences.

THE PENCIL INDICATOR

While all the aids discussed above permit only two degrees of physical freedom, an indicating device held and used like a pencil* in no way restricts the operators' manual movements. A pencil is, of course, an extension of the hand. Since the act of pointing with fingers and hands is greatly overlearned we would anticipate excellent performance in pip designation with a pencil. This expectation is amply confirmed in practice.

The earliest study known to the writer in this area (Baker and Ogilvie, 1951) employed a simulated PPI with a sweep-rotation rate of 4 rpm. Pips were 3/16 in. dia circles and at all times more were displayed than could be designated by contacting them with the pencil. Under instructions to " Go as fast as you can and be as accurate as you can ", subjects had little difficulty in designating over 100 pips per min during brief (2 min) trials. Of these " designations " 10 to 15 per cent were outside the circular areas simulating pips: the coefficient of correlation between speed and accuracy was +0.78.

In later studies by Baker *et al.* (1945a+b) and Boyes *et al.* (1954) a simulated 10 in. PPI was again used, with circular pips 2/16 in. dia and a rotation rate of 6 rpm. The metal pencil or stylus was 6 in. long and ½ in. in dia, with a tip 1/16 in. in dia. The task was to contact as many as possible of the large number of pips displayed, each contact being recorded as correct or incorrect (i.e. the pencil contacted the area around the pip rather than the pip itself). After each contact a microswitch, which was held in the other hand,

* Sometimes called the free-moving stylus. The engineering problems involved in applying this technique have been solved in two distinct ways. One (Fluhr and McLaughlin, 1959) employs an electrically conductive glass over the CRT, and the other (Gurley and Woodward, 1959) mounts light sensing elements inside the pen. In another use of this technique pips are interrogated for identity: when the stylus or light pencil is pointed at a pip and triggered, identity is made to appear on a small display above the CRT. This system of identity-on-demand was found (Schipper *et al*, 1956) to be as efficient as the continual display of identity using a clock code.

y 7100

US ARMY AIR DEFENSE BOARD

REPORT

OF

EVALUATION

PROJECT NR TF-2460

TRACK STICK VERSUS TRACK BALL

15 MAR 1961

61-2-5

XEROX

UNITED STATES ARMY AIR DEFENSE BOARD
FORT BLISS, TEXAS

15 MAR 1961

REPORT OF EVALUATION, PROJECT NR TF-2460

EVALUATION OF TRACK STICK VERSUS TRACK BALL

1. PURPOSE. To evaluate the track stick versus the track ball to determine which should be utilized in the AN/MSG-4 system.

2. AUTHORITY.

a. Directive. Disposition Form, ATDEV-4, United States Continental Army Command, 8 September 1960, subject: Request for Engineering Study, Track Stick vs. Track Ball.

3. REFERENCES.

a. Letter, ATDEV-05, 94th Artillery Group, 6 August 1960, subject: AN/MSQ-28 Packet Status Report.

b. Letter, ATDEV-04, 30th Artillery Brigade, 6 September 1960, subject: AN/MSQ-18 Packet Status Report.

4. DESCRIPTION OF MATERIEL. Track sticks and track balls contain digitizers or variable resistors which convert mechanical positions to electrical signals which control a marker on the console scope display and are used at the Radar Data Processing Center, Weapons Monitoring Center, Operations Central, and Coder-Decoder Group.

5. BACKGROUND.

a. Track sticks were initially installed in prototype AN/MSQ-18 and AN/MSQ-28 equipments. Production AN/MSQ-18 equipment utilized track balls. After the US Army Air Defense Board recommended that track balls replace track sticks in AN/MSQ-28 equipment, one track ball was installed in prototype Nr 1 AN/MSQ-28 for evaluation. Subsequently, half of the marker control equipment in prototype Nr 2 AN/MSQ-28 was equipped with track balls. US Army Signal Air Defense Engineering Agency (USASADEA) is proceeding with contractual action to install track balls in all AN/MSQ-28 equipment.

b. During the service test of the AN/MSG-4 system no firm agreement could be reached among test personnel as to which of these two items better served the various console operators. Accordingly, the US Army Air Defense Board requested that United States Continental Army Command make

ARRANGEMENTS FOR A HUMAN ENGINEERING TEST TO RESOLVE THIS QUESTION. SINCE NO EQUIPMENT WAS AVAILABLE FOR USE IN SUCH AN EVALUATION, UNITED STATES CONTINENTAL ARMY COMMAND DIRECTED THE US ARMY AIR DEFENSE BOARD TO CONDUCT A STUDY AND TO DECIDE WHICH DEVICE BETTER SERVES THE OPERATOR.

6. SUMMARY OF EVALUATION: A LARGE NUMBER OF OPERATORS HAVE BEEN TRAINED ON THE AN/MSQ-18 AND A LESSER NUMBER ON THE AN/MSQ-28. COMMENTS WERE OBTAINED FROM THE INDIVIDUALS CONCERNING THEIR PREFERENCE FOR THE TRACK BALL OR TRACK STICK. AN/MSQ-18 PERSONNEL STILL AT FORT BLISS AND THOSE IN OKINAWA EXPRESSED THEIR VIEWS. SEPARATE POLLS WERE TAKEN OF THE US ARMY AIR DEFENSE BOARD TEST TEAM IN EUROPE, OPERATORS OF THE TACTICALLY DEPLOYED AN/MSQ-28 IN EUROPE, AND THE REMAINING TEST PERSONNEL AT FORT BLISS. SPECIFIC COMMENTS WERE:

A. AN/MSQ-18. ALL PERSONNEL WERE UNANIMOUS IN THE PREFERENCE FOR THE TRACK BALL.

B. AN/MSQ-28.

(1) US ARMY AIR DEFENSE BOARD TEST TEAM IN EUROPE. TEST RESULTS AND LONG OPERATOR EXPERIENCE INDICATED THAT TRACK STICKS WERE FASTER FOR SUCH ACTIONS AS HOOKING AND ENTERING; WHEREAS, THE TRACK BALL WAS MORE ACCURATE FOR RATE-AIDED MANUAL TRACKING. THE TRACK STICKS WERE DESIRABLE FOR DETECTORS AND TRACK BALLS WERE MORE SUITABLE FOR THE TRACKERS IN THE RADAR DATA PROCESSING CENTER (RDPC). THE WEAPONS MONITORING CENTER (WMC) OPERATED WITH MORE EFFICIENCY WHEN TRACK STICKS WERE USED THROUGHOUT.

(2) TACTICAL UNIT IN EUROPE. THEIR VIEWS COINCIDE WITH THOSE EXPRESSED ABOVE IN PARAGRAPH 6B(1), EXCEPT THAT THERE WAS NO STRONG FEELING FOR THE TRACK BALL ON THE RDPC TRACKER POSITIONS. PREFERENCE FOR THE TRACK STICK WAS BASED ON THE FOLLOWING:

(A) TRACK STICK ENABLE BUTTON IS LOCATED ON THE STICK RATHER THAN IN A SEPARATE LOCATION AS IT IS FOR THE TRACK BALL. IN ADDITION, THE TRACK STICK ENABLE BUTTON HAS PROVEN TO BE THE MORE RELIABLE ITEM.

(B) TRACK STICK IS FASTER FOR ENTERING TRACKS, MOVES THE MARKER IN ONE SMOOTH MOTION, AND OPERATES IN AN EASIER AND MORE NATURAL MANNER.

(C) THE OPERATOR CANNOT LOSE THE MARKER SINCE THE TRACK STICK LOCATION REPRESENTS ITS POSITION AT ALL TIMES; WHEREAS, THE BALL REQUIRES A SEPARATE CENTERING BUTTON.

(3) US ARMY AIR DEFENSE BOARD OPERATORS AT FORT BLISS. THERE WAS GENERAL CORROBORATION OF THE COMMENTS EXPRESSED BY THE TWO PRECEDING GROUPS. SPECIFIC COMMENTS WERE:

(A) More marker movement is observed for the same increment of movement of track stick than for the track ball.

(B) The track stick has a firm grip and is not prone to slippage as is the track ball.

(C) Only one hand is required for track stick operations; whereas, the track ball requires two hands since the centering button must be activated separately.

(D) The mechanism under the track stick is more rugged. The track ball mechanism is damage-prone and requires more frequent adjustment.

(E) One particularly annoying feature of the existing track stick is the rubber boot used as a dust seal. A large displacement of the track stick compresses the rubber and causes the marker to jump back when the track stick is released momentarily, thereby introducing large errors in the tracking function. In addition, the rubber has a short life. A completely different approach to the dust seal problem should be used.

c. The principal area of disagreement among the AN/MSQ-28 experienced personnel involves the use of the track ball in the RDPC for the tracking operation. It has always been agreed that the track stick is best for detector operations. The six consoles in the RDPC can be used interchangeably for either operation. This optional use is governed by target load, state of maintenance of the consoles, and tactical SOP. In view of this governing uncertainty, the only solution is to provide a plug-in module of a track stick and a separate module of a track ball for each console. Only then can all contingencies be accommodated.

7. CONCLUSIONS.

a. AN/MSQ-18. Track balls as currently installed on production equipment are satisfactory and should be retained.

b. AN/MSQ-28.

(1) Track sticks should be provided exclusively in the WMC.

(2) Six plug-in track ball and six plug-in track stick modules should be designed and provided for use in the RDPC.

(3) The rubber boot dust seal for the track stick is unsatisfactory and should be replaced by a mechanism which is more desirable and does not influence track stick movement.

(4) A HIGHER RATIO OF TRACK STICK MOVEMENT TO MARKER DISPLACEMENT OF THE "FINE" POSITION FOR THE TRACK STICK IS DESIRABLE. BETTER TRACKING ACCURACY WOULD RESULT.

(5) THE RATIO OF TRACK BALL MOVEMENT TO MARKER DISPLACEMENT FOR THE "COARSE" POSITION IS TOO HIGH. A LOWER RATIO WHICH PROVIDES MARKER DISPLACEMENT FROM SCOPE CENTER TO MAXIMUM DEFLECTION WITH ONE TRACK BALL MOVEMENT IS DESIRABLE. MOVEMENT IN THE "FINE" POSITION IS SATISFACTORY.

8. RECOMMENDATIONS. IT IS RECOMMENDED THAT:

A. TRACK BALLS BE UTILIZED IN ALL AN/MSQ-18 EQUIPMENT.

B. TRACK STICKS, MODIFIED TO INCORPORATE CHANGES LISTED IN PARAGRAPH 6B(3), 6B (4), AND 6B (5), ABOVE, BE UTILIZED IN BOTH PROTOTYPE AND PRODUCTION WMC's.

C. BOTH PROTOTYPE AND PRODUCTION RDPC'S BE PROVIDED WITH COMPLETE SETS OF MODIFIED TRACK STICKS AND TRACK BALLS AS OPTIONAL PLUG-IN MODULES.

25X1

COLONEL, ARTILLERY
PRESIDENT

LIBRARY COPY

D.S.I.R. CONFERENCE ON AUTOMATIC CONTROL

This paper, read at the above Conference, has been reprinted from *Automatic and Manual Control*, published by Butterworths Scientific Publications, Bell Yard, Temple Bar, London, W.C.2, price 50s. This volume contains all the papers read at the Conference, together with the Discussions arising from them.

Approved For Release 2005/05/02 : CIA-RDP78B04770A001200010093-7

Free-moving Versus Fixed Control Levers in a Manual Tracking Task

C. B. GIBBS
With the Assistance of
J. C. BAKER
Medical Research Council
Applied Psychology Research Unit
in the Psychological Laboratory, Cambridge, England

The main experiments were designed to set a task of manual tracking, with two alternative methods of operating the control lever. In one case a normal free-moving joystick was used, and in the other the joystick was secured, but could be deflected slightly by the application of pressure. The pressure control was found to be more accurate in tracking tests; further tests showed that single corrections could be made more quickly, to a given level of accuracy, when the pressure control was used.

INTRODUCTION

It is customary to provide free-moving control levers or handwheels, etc., to control manually operated machines or systems. An alternative type of control lever has been designed, at which an applied pressure deflects the lever although these minute movements are imperceptible to the operator. The deflections are converted and amplified by electronic means and the system is controlled by varying the pressure applied to the control lever.

The main purpose of the present experiments was to compare the efficiency of the two methods of control. The results could be valid only if an optimal range of movements was compared with an optimal range of pressures, and preliminary experiments were designed to determine these zones.

APPARATUS

The apparatus set the operators a task of manual tracking with velocity control. A course-setting mechanism, with two rotating cams, caused a spot of light to wander in two dimensions across the screen of the cathode ray oscilloscope. The 'standard' course varied the velocity of the light continuously in two dimensions. The traverse cam, that moved the light from left to right, could be changed to give a more 'difficult' course. Both courses are plotted in Fig. 1 to show the movement of the eye in degrees per second when fixated on the light. Eighty seconds were required for each revolution of the cams; the course was then repetitive, and a standard period of practice was 15 min for all operators.

The subjects sat directly facing the screen of the C.R.O., and 14 in. from it; both hands held at approximately elbow height a joystick that could be rotated or deflected about a universal coupling, to control the spot movement in elevation and traverse.

Elbow supports were provided. The lever was mounted horizontally, pointing towards the operator.

In the *free-moving* conditions, a hand movement to the right or left, up or down caused the spot of light to move in the same direction and plane as the hand. This gave the optimal directional relationship for learning. The joystick controlled the movements of the spot of light, against the offsetting action of the course setting mechanisms, and the operator could therefore attempt to hold the light stationary at the fixed index. Spot deviations were summed separately by four counters, driven by the central member of the differentials (Fig. 2), which showed errors of 'high', 'low', 'right' and 'left'. The

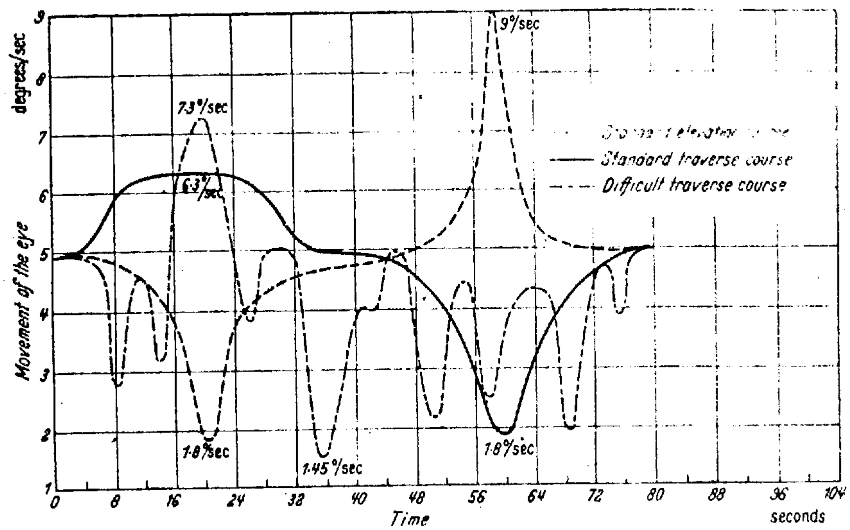


Fig. 1

errors were recorded at each revolution of the cams and the counters recorded one unit per 0·05 in. of spot movement. This method of recording was used in the main tracking tests and registered only the total extent of spot movement per 80 sec, and not the time of persistence or frequency distribution of the errors. The limitations of counter recording are well known, but the method was suitable for certain practical applications that were visualized. A small number of continuous chart records were taken to confirm that counter recording was not giving biased results in favour of the pressure control, by its selective action in eliminating certain characteristics of the total performance. The diagrammatical layout of the gear is shown in Fig. 2.

Displacement/velocity or rate control was used and each separate angular position of the joystick resulted in a different velocity and direction of movement of the spot of light. The length of the joystick and the amplification of the signal could be altered so that different 'gear ratios' could be obtained between the amount of hand movement and the velocity given to the light. The gear ratio remained approximately constant over the whole range of joystick movement. Several gear ratios were compared to determine the optimum, and this standard ratio was used in comparing the methods of Free Moving and Pressure Control; 1 mm of hand movement then altered the velocity of the spot of light, subtended at the eye, by 0·53°/sec, and the length of the lever was then 19·5 in. from fulcrum to hand grip.

In the *pressure control* arrangement of the apparatus, the situation was exactly as before except that the joystick was secured at the end remote from the operator. Applied pressure would then cause slight deflections of the lever in the same plane and directions as before. The joystick deflections were converted and amplified*, and used to control the movements of the spot, as in the free-moving arrangements. The pressure/velocity gear ratio was again approximately constant over the range that was used.

A number of different pressure/velocity ratios were tested and a standard optimal ratio was selected and used in comparing the methods of free moving and pressure control.

In the standard conditions a force of 1 oz at the lever altered the velocity of the light by 0·26°/sec subtended at the eye. *The time-constant of the control system* is an important

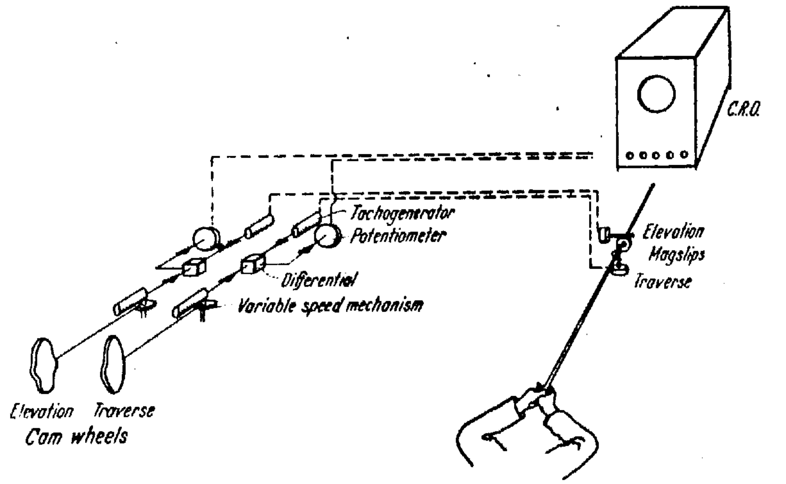


Fig. 2

variable and may have considerable effects upon human performance. It was kept at a fixed setting during the present experiments, with an estimated value of approximately 0·1 sec.†

The *single correction* series of experiments was designed to compare the times taken to correct a given amount of error at the screen, using the standard pressure and standard free-moving methods of control. Small target spots were painted on the screen, 40 mm distant from the centre. The task was to move the spot of light from the paint spots to within a small circle at the centre of the screen with the highest possible speed. The course setting mechanism was running during the tests and the spot tended to wander at a fixed rate, so that the operator had the dual task of (*a*) making a large corrective movement, and (*b*) compensating for a constant course input. The period between (*a*) the starting signal to the subject, (*b*) the initial movement of the spot of light, and (*c*) the instant when the spot of light was arrested within the circle were recorded on a paper chart moving at a constant speed. This test gave a preliminary indication of the relative times of persistence of errors in the two methods. These records could be used to supplement the data from the main tracking tests (where counters were used and only the amplitude of errors was recorded). It also compared the methods of control in a discontinuous task, in addition to the continuous task of tracking.

* The amplifiers were used in both the pressure and free-moving conditions, but the gain was much greater in pressure control.

† The time constant is defined as the time taken to reach a new steady speed after a sudden movement of the lever, if the initial rate of change were maintained.

Approved For Release 2005/05/02 : CIA-RDP78B04770A001200010093-7

TEST DESIGN AND RESULTS

Subjects. The subjects used in all the experiments were men aged 19–26; the majority had had some previous experience in tracking.

Practice effects and statistical methods. A control group of eight men continued tracking practice on both levers for eighteen periods of practice and little improvement was found after the sixth period. All the subjects had at least this amount of practice before comparisons were made between the controls, except for one test that was designed to compare learning effects. Practice effects were equalized before any conditions were compared, by presenting the conditions in Latin Square form, or in alternate order to two equal groups of matched subjects, when only two conditions were compared. All results were tested by the normal statistical methods.

The comparison of gear ratios. Eighteen subjects were used in these tests and seven different movement/velocity ratios were compared ranging from 0·17°/sec per 1 mm to 3·3°/sec per 1 mm. There was no significant alteration in performance within the range 0·77°/sec to 0·17°/sec per 1 mm of hand movement, but performance was significantly worse within the range of 1·08°/sec to 3·3°/sec per 1 mm of hand movement. The standard gear ratio of 0·53°/sec per 1 mm lay within an optimal range.

The same subjects also tested six different pressure/velocity ratios ranging from 0·04°/sec to 1·10°/sec per 1 oz. Performance was equally good when the ratios lay within the range of 0·26°/sec to 0·4°/sec per 1 oz, but there was statistical evidence of deterioration when the ratios were 0·66°/sec, or 1·1°/sec, per oz. The standard ratio of 0·26°/sec, per 1 oz, lay within the optimal range and did not cause fatigue in the test conditions.

The single correction experiments. Sixteen subjects were used in these tests, and all subjects used both the pressure and free-moving controls. There was an average interval of 0·426 sec between the signal to start a correction and the initial movement of the spot of light when the free-moving control was used, but this was reduced to 0·313 sec with the pressure control, and the difference was highly significant. The average time to *complete* the correction to the specified degree of accuracy was 4·113 sec with the free-moving control, but this was reduced to 3·073 sec with the pressure control, and the difference was again highly significant.

The comparisons between the standard pressure and standard free-moving conditions using the standard course. Two groups of eighteen subjects (Groups A and B) were matched in initial ability on a preliminary check test of tracking skill on the actual equipment.

Group A practised the standard pressure arrangement with the standard course as their first task for three 15 min runs. One run of practice was given each day. Their error scores were recorded at each revolution of the cams and the average group scores per run are plotted as the dotted curve in Fig. 3.

Group B practised the standard free-moving arrangement under similar conditions and their average error scores are shown by the continuous curve of Fig. 3.

At this stage, comparisons were made between the groups using both the measures of the average score on the third run, and the average of the best scores on any run out of the first three. There was a significant difference in favour of the pressure control, using either measure. The two groups then exchanged tasks and continued practice for three further periods of 15 min on their new task. Further comparisons were made at this stage and the pressure control was significantly better again, using either measure.

An interesting finding was that the subjects with high initial ability generally retained their superiority with increased practice, irrespective of the control that was used, but the relative improvement of initially poor operators was greater at the pressure control. This implies that there will be less difficulty in selecting operators where a pressure control is used.

The comparisons between the standard pressure and standard free-moving arrangements using the difficult course. Twenty-four subjects were used to compare the standard pressure and standard free-moving arrangements with the difficult traverse cam substituted for the standard traverse cam. All the subjects tested both the pressure and free-moving controls.

The standard run was of 15 minutes' duration in these tests, and one run in pressure and one in free-moving control was given to each subject.

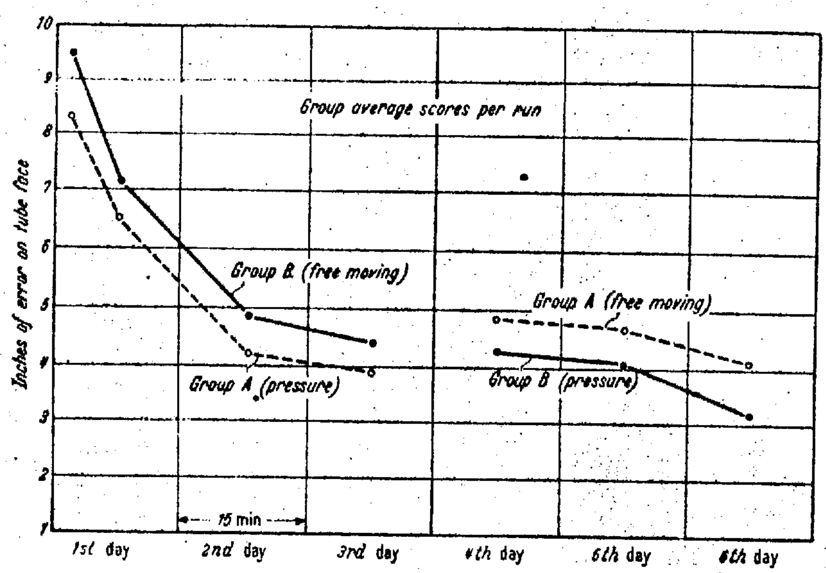


Fig. 3

The average error score was 1565 units using the pressure control, but the errors were increased to 1887 units with the free-moving control, and the superiority of pressure control was highly significant.

DISCUSSION

The experiments are at a preliminary and exploratory stage, and any general interpretation of the results must await the completion of further experiments. The real superiority of the pressure control has been demonstrated, and optimal ranges of pressure and movement have been found. These findings, however, may be valid only within certain physical limits, and different methods of recording the errors may possibly affect the findings. Further experiments are proceeding and will be extended as further apparatus becomes available.

Experiments on finger operated joysticks of the pressure and free-moving types have reached an advanced stage, and support the main conclusions of the present experiments. Viscous friction and inertia have been varied within wide limits at the free-moving joysticks, and the pressure control remains superior.

The performance criteria used may of course affect the results if two error scores with different distributions are compared. Occasional spikes in the error curve will be emphasized if the root mean square errors are compared, whereas they will have much less effect on the modulus mean error (HICK and BATES[1]). Counter recording will only measure the peak to peak, or peak to trough values in the error curve, and no errors would be recorded if target rates and following rates were exactly matched, even when positional or point of aim errors were actually present. There are other limitations in other methods of recording, such as measuring the time on aim, and the best method of recording experimental results is dependent upon the immediate practical applications of the data.

In the present case, rate errors were much more important than point of aim errors, since the effects of the former are amplified in a computing mechanism, whereas the latter remain unchanged in the practical application.

The selective action of counter recording was therefore acceptable for preliminary experiments, since high frequency oscillations in the error curve would have a much greater effect on the overall accuracy of the system than low frequency errors in point of aim.

It was recognized, however, that other applications would require different criteria, and alternative criteria have been used. The results of the single correction experiments show that it is extremely unlikely that point of aim errors persist for longer periods with the pressure control. A very large number of samples of point of aim were taken by the use of the four counters, since the instantaneous difference between opposed counters would show aiming errors. These differences were calculated at 80 sec intervals for all the subjects. Experiments are proceeding, using chart recording and the criterion of modulus mean error, and six records have been taken. The evidence that is available to date suggests strongly that counter recording is not giving an advantageous bias to the pressure control, but rather that its selective action is favouring the free-moving control. This has not yet been rigorously proved, however, and comparisons have not yet been made between the controls using different time constants, orders of controls or jolting conditions.

ACKNOWLEDGMENTS

Our thanks are due to Mr J. J. YOUNG, who first directed attention to many practical applications for pressure controls, and to Mr H. S. MILES and Mr J. H. ASKEW for invaluable help with the apparatus.

REFERENCE

HICK, W. E. and BATES, J. A. V. *The human operator of control mechanisms* (1950) M.O.S. Monograph No. 17, 204.

[*Discussion on this paper will be found on p.* 494 *et seq.*]

1 Adm Pha. G Drug

2 " " Mailing all files

3. Film Trng ~~materials~~

Approved For Release 2005/05/02 : CIA-RDP78B04770A001200010093-7

25X1

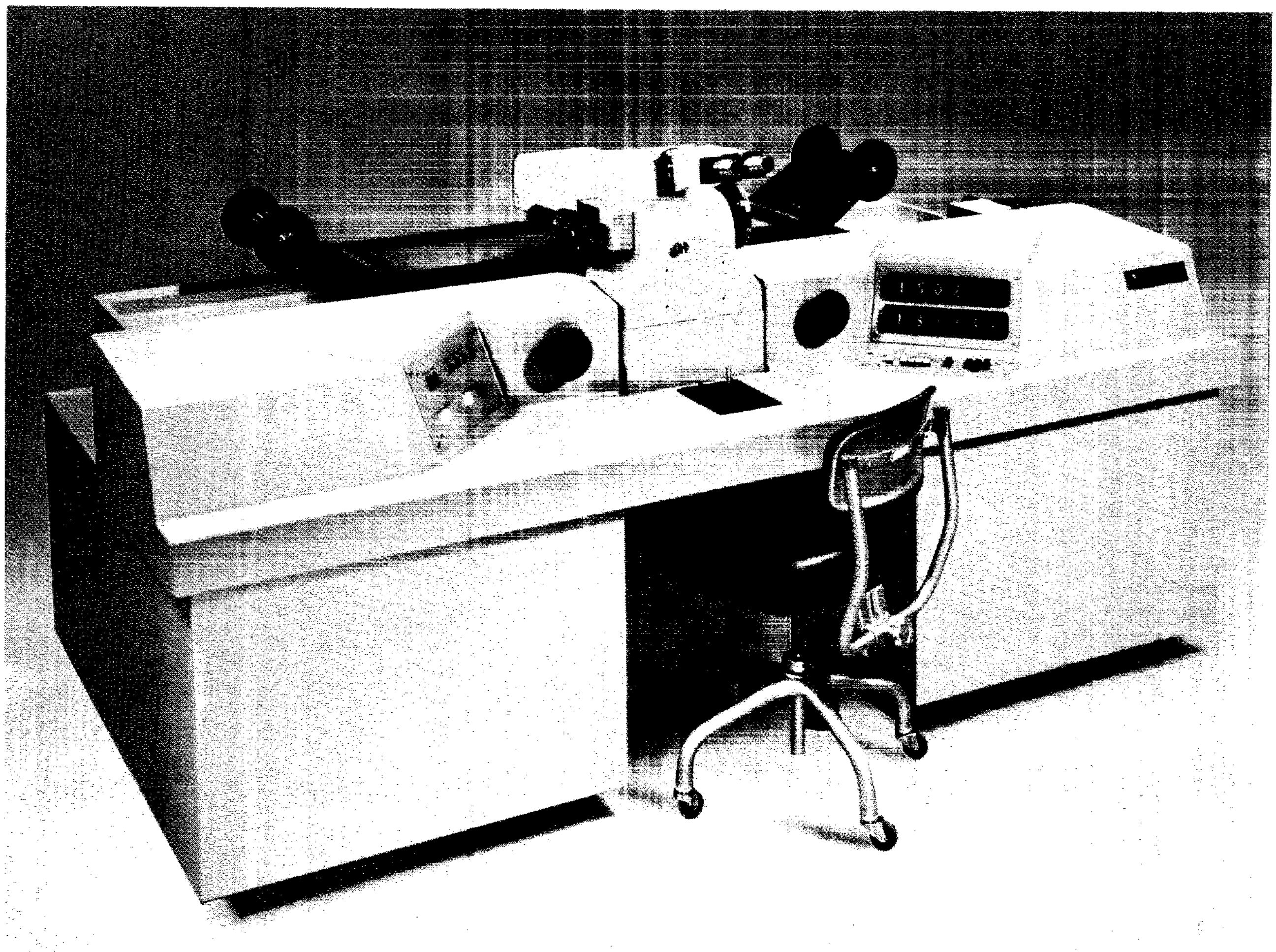
[redacted] TYPE 1350 LARGE FORMAT COMPARATOR

25X1

[redacted] Type 1350 Comparator, a precision photographic data reduction system with digitized readout, provides *continuous* measurement over the largest format area yet available . . . 36 inches in X by 10 inches in Y. Any point in the format is easily positioned for measurement by a joystick control which affords continuously variable slew speeds for X and Y motions.

FEATURES:

- Exceptionally large format, 910 mm x 250 mm.
- Binocular microscope viewing system, 10X through 40X, enhances measurement accuracy.
- Film stage accommodates up to 400 feet of 9.5″ roll film — utilizes pressure platen.
- Substage illumination to aid operator in identification of measurement points.
- Slew speeds continuously variable in range from 15 mm per second to 5 mm per minute.
- Accuracy of 5 micrometers or 0.001% of total travel in either coordinate. Digitized readout to least count of one micrometer.
- Digitizer formatting capability allows variation in readout order of six-digit words.
- Illuminated dual display shows X and Y axis stage position.
- Self-contained leveling system.
- Controls and displays located for convenient operation and observation.



[redacted]

25

2

OPTIONS:

- Digitizer output to card punch device with other output options available.
- Special film stage with vacuum hold-down at each end of format. Air puck system surrounds field of view, eliminates emulsion contact.
- Self-contained environmental control system.

ENVIRONMENTAL REQUIREMENTS:

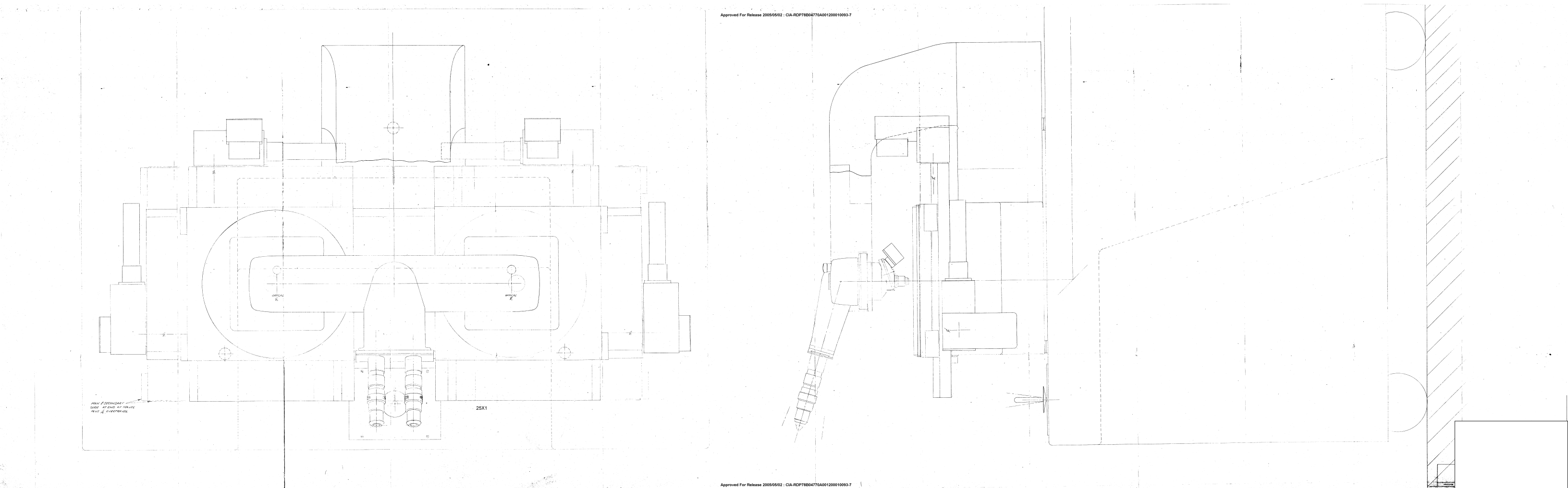
Precise measurement is a function not only of the instrument design and the operator's experience but also of the ambient environmental conditions to which the instrument is subjected. We recommend, therefore, that the [redacted] Type 1350 Comparator be used in a closely controlled environment at an ambient temperature of 70°F ± 1°F and a relative humidity of 50% ± 5%. 25X1

[redacted] is a widely recognized leader in development and manufacture of a complete line of precision screw type measuring instruments for use in working with all the formats now normally encountered in data reduction by scientific laboratories, research organizations and industry. Instruments are available in either the metric or English system of measurement. 25X1

[redacted] reserves the right to depart from the details of design in the interest of improving its instruments. 25X1

25X1

Approved For Release 2005/05/02 : CIA-RDP78B04770A001200010093-7



Approved For Release 2005/05/02 : CIA-RDP78B04770A001200010093-7